JELA

New Orleans District

US Army Corps of Engineers

WETLANDS RESTORATION STUDY

WEST JEFFERSON PARISH, LOUISIANA

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1. INTRODUCTION

Thousands of acres of wetlands comprising the upper reaches of the Barataria Basin flank the west bank of the Mississippi River in Jefferson Parish, Louisiana. These wetlands are valued for their fisheries and recreational value as well as their ability to protect the inhabited areas of the Parish from storm surges. The wetlands in this area are being stressed and functionally degraded or lost as a direct result of human activities that have limited traditional sources of fresh water and nutrients, and by the effects of subsidence. Historically, flows from the Mississippi River provided the fresh water, nutrients and sediments needed to maintain healthy wetlands, and counteract the natural subsidence associated with deltaic systems. Construction of flood and hurricane protection levees has eliminated the interconnection between the River and the wetlands. As a consequence, subsidence and salt water intrusion have degraded the vigor of the vegetative communities, and these wetlands are transitioning to open water.

An annually occurring hypoxic zone, an area in the Gulf of Mexico of low oxygen content, has been occurring in the Gulf westward from the mouth of the Mississippi River. This hypoxic zone has been attributed to high quantities of nutrients entering the Gulf from the Mississippi River. The nutrients enter the River from a variety of sources including primarily agricultural and urban stormwater runoff and, to a lesser extent, from direct discharge from a large number of wastewater treatment facilities. Jefferson Parish's West Bank wastewater treatment facilities currently discharge treated wastewater effluent into the Mississippi River. Limits are likely to be imposed in the future on nutrient discharges into the Mississippi River, which could lead the Parish to alter its current treatment processes, possibly requiring additional treatment processes to accomplish nutrient removal.

From a regulatory view, the State of Louisiana and the Federal government have begun the process of addressing wetlands loss and the hypoxic conditions in the Gulf of Mexico. Future limits on nutrient discharges to the Mississippi River may require a 30 percent reduction. Jefferson Parish is already in the process of preparing a long-term

strategy for wastewater treatment on the Parish's West Bank to address the need for added capacity associated with projected population growth.

Federal, state and local planners have found that wetlands restoration techniques that use treated municipal wastewater effluent as a source of fresh water and nutrients have been proven to be safe and effective in Louisiana and elsewhere in the nation. Thus, the need to address wetlands degradation and excess nutrients in the Mississippi River, and the Parish's need to chart a long term course for its wastewater treatment program have combined to make it an opportune time to evaluate an alternative that has the potential for addressing all three needs. Jefferson Parish and the U.S. Army Corps of Engineers, New Orleans District (USACE NOD) have conducted a joint study to define the technical and cost feasibility associated with a project designed to both restore the health of wetlands and to assist in the Parish's long term wastewater treatment needs. The study evaluates the potential of recycling the treated wastewater effluent by utilizing it as a source of fresh water and nutrients for wetlands on the west bank of the Mississippi River in Jefferson Parish.

This Phase 2 report continues the documentation of the study done to evaluate the feasibility of wetlands restoration in West Jefferson Parish, Louisiana through the application of treated municipal wastewater. Phase 1 of the study was completed in January 2003 with the issuance of a report evaluating the overall feasibility of the concept. The first phase feasibility analysis was conducted to determine the technical, economic and environmental feasibility of using treated municipal sewage for the purpose of wetland restoration on the west bank of Jefferson Parish, Louisiana. That report concluded that there were adequate acreage of wetlands in west Jefferson Parish in need of restoration and recommended that additional analysis be conducted. This second phase report takes a more detailed look at the feasibility and targets specific sources of water and specific wetlands to be restored. Updated cost estimates are also presented in this report.

The Corps was requested to provide technical assistance to Jefferson Parish to develop recommendations for wetland assimilation technology on the West Bank of Jefferson Parish. The project team conducting this study consisted of environmental and engineering professionals from several firms and federal and local government agencies. Waldemar S. Nelson & Co., Inc.(NELSON) served as the prime contractor on the study and coordinated the efforts of the team under the direction of the Corps Project Management. Other major team members included CH2MHILL's office in New Orleans, Louisiana, Comite Resources, Inc in Baton Rouge, Louisiana and Dennis Butler of New Orleans, Louisiana. The Environmental (Marnie Winter), Public Works (Herb Miller) and Sewerage (Brett Todd) of Jefferson Parish also participated actively in the study.

After more detailed study, the feasibility of using treated municipal effluents for wetland restoration in west Jefferson Parish has been validated. This second phase report screened the number of viable alternatives to be considered and presents updated cost estimates to assist the Parish in evaluating whether or not to implement this program as part of their overall strategy for providing for cost-effective and efficient sewage treatment for west bank residents. While the monetary benefits of wetland restoration are not presented in this report, Parish planners should realize that more vibrant and healthy wetlands south of developed areas will provide benefits to the Parish through enhanced storm protection, storm water treatment, recreation and tourism, and numerous other factors.

The following sections of this report present background information, information on the alternatives for both sources of water and target wetlands to be restored, updated project cost estimates, an environmental analysis of the program and finishes with summary and conclusions. Obviously an entire body of scientific and engineering knowledge has been built up on this technology. Appendix A contains more information about the science and Appendix B contains case histories of similar projects.

2. POTENTIAL SOURCES OF TREATED EFFLUENT

a. Alternatives Evaluated

Jefferson Parish operates three major wastewater treatment facilities that serve the main, unincorporated portions of the West Bank of the Parish. These facilities are located in the Bridge City, Marrero and Harvey areas of the West Bank (Exhibit 1). In Phase 1 eight alternatives were evaluated including the upgrading of all three existing facilities and piping some or all of the effluent to the wetlands. Harvey Canal, Avondale, Landfill and Hero were the four consolidated options considered. Table 1 was produced as a result of that evaluation and is shown here modified based on nutrient information provided by the Parish.

Table 1. Unit Costs for Each Alternative

Site	Receiving Area Required (Ac)	Wetland Units	Flow (MGD) (1)	$/MGD
All three upgraded:	11,800	2,3,4,5	30.3	1.7 million
Harvey	5,400	3,4,5	14.5	1.8 million
Marrero	4,300	2,3,4	11.3	0.7 million
Bridge City	1,900	2,3	4.9	3.7 million
Harvey and Marrero(2)	9,700	2,3,4,5	25.8	1.3 million
Consolidated Plants:				
Harvey Canal	11,800	2,3,4,5	40	1.5 million
Avondale	11,800	2,3,4,5	40	1.7 million
Landfill	11,800	2,3,4,5	40	2.1 million
Hero	11,800	2,3,4,5	40	0.9 million

(1) Flows presented for individual plants are present day while flows for consolidated plant locations are future projected flows.
(2)For the Combined Harvey and Marrero alternative the flows come from the existing plan locations.

It was decided in a meeting with the USACE, NOD, Jefferson Parish and the technical team on January 14, 2003 to limit the alternatives assessed in Phase 2 to those five alternatives shown in Table 2 due to their cost effectiveness. These include the Marrero and Harvey plants individually

and combined and the Harvey Canal and Hero consolidated plant locations. The other options were not chosen mainly due to their higher $/MGD values. By looking at these alternatives all candidate wetland areas developed in Phase 1, excepting a small area in the northern part of Area 2 would be assessed in detail. All reasonably attractive effluent discharge scenarios would be assessed as well. Plant locations, routing of effluent pipelines and candidate wetland areas are all shown in Exhibit 1.

Table 2. Costs for Each Project Alternative

Site	Receiving Acres Required	Wetland Units	Flow[1] (MGD)	$/MGD
Individual Plants:				
Harvey	5,400	3,4,5	14.5	1.8 million
Marrero	4,300	2,3,4	11.3	0.7 million
Combined Harvey and Marrero[2]	9,700	2,3,4,5	25.8	1.3 million
Harvey Canal Consolidated	11,600	2,3,4,5	40	1.5 million
Hero Consolidated	11,600	2,3,4,5	40	0.9 million

(1) Flows presented for individual plants are present day while flows for consolidated plant locations are future projected flows.
(2) This alternative addresses wetlands discharge from both of these plants from their present location.

Costs identified in the table on a $/MGD basis indicate that the Marrero only alternative is the most cost effective with a consolidated plant at the Hero location being almost as cost effective. Note that the cost estimates presented herein do not include any costs related to piping effluent from other locations to the treatment plant site.

b. Characteristics of Effluent

Hydraulic and effluent values that form the basis of this wastewater recycling/wetlands enhancement analysis are presented in Table 3 and derived from two recent studies prepared by the Parish:

Linn & Ocean
No Light Point
Really Big Bldg orig
Turning At Time
Sinks down

Nitrogen
Nitrate
Do
But Need Nitr
orig
Pressure

Stays in
Cause in
Low Lobes

Shallow Ponds
& Slow Moving
Fast Moving Waterways

Input
N
on used up
in constant.

- The West Bank Section 201 Facilities Plan Update, prepared by Steimle and Associates, 2001.
- West Bank Consolidation Study prepared by Camp, Dresser and McKee, (Draft, 2002)

The values in Table 3 were agreed upon by the Parish and Corps of Engineers as the values upon which this evaluation was to be developed. The Consolidated Option values represent the quality and quantity that will likely be produced by a future, consolidated wastewater treatment facility. The Marrero Option is based on the currently proposed expansion and the Harvey Option is based on the current Harvey treatment plant.

In 1999 average daily flow and peak daily flow from the existing facilities was 22.4 MGD and 80.3 MGD respectively.

Table 3. Parameter Loadings

PARAMETER	CONSOLIDATED OPTION	HARVEY OPTION	MARRERO OPTION
Max Monthly Average Daily Flow	60 MGD	14.49 MGD	11.26 MGD
Peak Daily Flow (PDF)	120 MGD	28.98 MGD	22.52 MGD
Peak Hydraulic Capacity	180 MGD	43.47 MGD	33.72 MGD
BOD Loading @ ADF (90% Removal)	4,500 lb./d	1,087 lb./d	845 lb./d
TSS Loading @ ADF (90% Removal)	6,370 lb./d	1,538 lb./d	1,195 lb./d
BOD Loading @ MMADF (85% Removal)	8,820 lb./d	2,130 lb./d	1,165 lb./d
TSS loading @ MMADF (85% Removal)	14,332 lb./d	3,461 lb./d	2,690 lb./d
Nitrogen Loading - Nitrate + Nitrite - TKN	 0.05 mg/L 17 mg/L	 0.03 mg/L 15 mg/L	 0.05 mg/L Unknown
Phosphorus Loading	1.2 mg/L	1.1 mg/L	Unknown

Bacteriological quality of the effluent is assumed to be 200 monthly average and 400 maximum daily average fecal coliform colonies per 100 milliliters, following standard disinfection.

Discharge Monitoring Reports with effluent nitrogen and phosphorus values were provided by the Parish. There was no TKN or Phosphorous testing done at Marrero, only Harvey and Bridge city.

c. Current Situation in Parish

The east bank of Jefferson Parish is essentially fully developed. The main area left for growth in Jefferson Parish is on the west bank of the Mississippi River. That area has the potential to double in population at some time in the future. To accommodate for the expected growth, Jefferson Parish is in the process of preparing long term (20 or more years) plans for its West Bank Wastewater collection and treatment systems

The Parish is near completion of a draft of its long term plan. The main concept to be decided in the long term Parish report is whether to consolidate or expand the existing treatment plants. At this time, viable alternative concepts include:

- Expansion at the three existing sites and continuing to discharge to the Mississippi River at three separate locations.
- Expansion at the three existing sites and redirecting the treated discharges to the wetlands identified in this report.
- Consolidation of all treatment units to a single location and continued discharge to the Mississippi River from that location.
- Consolidation of all treatment units to a single location and redirecting the treated discharge to the wetlands identified in this report.

The results of the evaluation presented in this report will be incorporated into the long term plan as two sub-alternatives:

- Expansion of Existing Sites Along With Wetlands Discharge
- Consolidation of Treatment to A Single Site Along With Wetlands Discharge

No decision has been made by the Parish to select either a Consolidated Plant Alternative or one that preserves treatment at the current three sites. That decision will be made in the coming year. Selection of a system-wide alternative for any wetlands discharge will be a part of the Jefferson Parish final long term plan and alternative selection.

There has, however, been a decision to proceed with construction of a 5 MGD expansion of the existing Marrero Treatment Plant. Those plans are in final review, and construction could begin as early as the first quarter of 2004.

The Marrero Facility upgrade will be accomplished by adding an entire treatment process train. The expansion and the existing treatment processes are both trickling filter, activated sludge designs. Since nitrification of ammonia is dependent on longer sludge age/mean cell residence times, the facility upgrade is expected to have the flexibility to produce a nitrified effluent that is more desirable for use in the wetlands discharge program. The proposed expansion will increase the discharge to 14 MGD. Using the new Marrero STP levels, a nitrate level of 15 mg/L and assuming that all of the nitrate is required to be removed from the effluent, approximately 5,300 acres of wetlands will be necessary to treat the effluent from this facility. Areas 2, 3 and 4 have enough acreage to accommodate this flow. This acreage assumes that all of the nitrate has to be removed by the time the

water reaches the flotant marsh, however there is recent evidence that the marsh could actually benefit from the addition of nutrients.

The Marrero facility flows are primarily derived from residential and commercial uses. Industrial users in the service area typically have their own treatment facilities, and discharge no process water into the public system. The Marrero facility's effluent therefore should have typical municipal wastewater characteristics.

Under this scenario, treated flows from the expanded Marrero site would be pumped to the vicinity of the Ames Pumping Station, approximately 4,500 feet. The first target wetlands would be in Wetlands Unit 2 which lies immediately over the levee with additional wetlands available in Wetland Units 3 and 4.

d. Recommended Project

Large scale wetlands treatment projects are new to Louisiana. From the range of alternatives identified in this report, the Parish has chosen the following criteria for evaluation of wetlands discharge alternatives in the long term planning document:

- The wetlands treatment concept must be accepted in writing as a long term option for Jefferson Parish by the appropriate federal and state regulatory agencies.
- The alternative should permit phased implementation to allow for site-specific evaluation of wetlands response.
- The alternative should permit phased implementation to minimize financial risk.

The most probable scenario would be to construct the facilities in phases. The treated effluent discharge from the Marrero plant has been identified as

the least cost, highest benefit alternative with the least risk. The benefits of this alternative are:

- Low cost, $ 7.9 million
- Significant treated wastewater discharge volume, 14 MGD
- Flexibility to revert to the existing Mississippi River discharge in the event of an emergency at the plant, regulatory changes, etc.
- Ability to fit easily into a system-wide consolidated plan, should the Parish's final long term plan select that option
- Least loss of assets constructed in the initial phase of the wetlands program. (If a more expansive option is chosen in subsequent phases, the wetlands diffusion pipelines south of the Ames Pumping Station should be reusable.)
- By the time the next phase of wetlands discharge is ready for implementation, sufficient site-specific data would be available to support any expanded permit application.

Although the Parish has made no decision on the consolidation issue and related wetlands discharge options at this time, the Marrero Plant Expansion presents an opportunity to begin the wetlands treatment concept with limited risk because of its relatively low cost. This makes the Marrero Plant an ideal pilot project for Jefferson Parish to consider.

3. DETAILED WETLAND UNIT SELECTION

The areas most in need of restoration within the Park were evaluated through three different mechanisms as delineated below:

- Recommendations received from the NPS regarding areas most in need of restoration based on their familiarity and knowledge of the area
- Evaluation through on-site inspections,
- Evaluation through the use of remote sensing to determine areas with lower chlorophyll levels in vegetation (indicative of plant stress).

a) **National Park Service Recommendations -** Mr. David Muth recommended that forested areas be used and marsh areas avoided when discharging the treated effluent into the wetlands. No other recommendations were made with respect to areas within the Park thought to be most in need of restoration.

b) **On-Site Inspection -** On Jul. 28, 2003, a field trip was carried out to potential receiving areas for wastewater assimilation. Present on the field trip were Dr. John Day and Jason Day, Comite Resources; Mr. David Muth of NPS, and Mr. Chuck Parker of Nvision. The primary purpose of the trip was to view the different habitats of the park, especially with regard to potential wastewater assimilation. A secondary purpose of the trip was to obtain an initial idea of the potential of using remote sensing to assess vegetation health.

Figure 1. Site 2 (GPS 3) Crossing Kenta Canal

The trip confirmed a number of analyses and conclusions arrived at during earlier phases of the project. The vegetation zonation patterns observed in existing aerial imagery of the area were confirmed. From the crest of the natural levee, the elevation decreases to near sea level in the floating wetlands. Upland communities dominated by oak and other hardwood species dominate the well-drained portions of the natural levee. With decreasing elevation, drainage becomes poorer, stressing these terrestrial communities. At the interface between the upland community and forested wetlands, upland species were stressed, dying and/or dead. There was regeneration of cypress and tupelo in this zone. With increasing distance from the levee, the cypress-tupelo swamp thins and regeneration ceases. Ultimately, the swamp is replaced by a flotant marsh community. These observations confirmed

earlier conclusions that the best place for discharge of the treated effluent is at the upland-forested wetland interface.

Figure 2. Site 5a (GPS 6) Old Oak Forest

Cypress swamp along the Millaudon Canal has received both untreated and treated wastewater for many years. The cypress in this area are large , robust, and healthy looking. This is the best stand of cypress that was observed during the trip. It seems likely that the long term wastewater discharge has substantially enhanced the productivity of this area. The cypress community along Millaudon Canal is indicative of what the impact of wetland assimilation will likely be. The cypress forest in this area has been affected by sewage discharge from the Ames wastewater treatment facility in Marrero (treated and untreated) and upland runoff (through the Ames pumping station) for decades. Individual trees are tall and richly foliated, in comparison with cypress in other

areas of the swamp. The forest appears healthy and productive. It is very likely that this is due in large part to the fertilizing effects of the discharge.

Figure 3. Cypress Tupelo with Low Understory and No Regeneration

Overall, the field trip confirmed earlier expectations about the structure of the wetland community These include the vegetation zonation from the natural levee ridge to the flotant marshes. The stressed condition of the natural levee community at the toe of the natural levee and the general lack of regeneration in the cypress-tupelp community were also confirmed. An important observation was that the cypress community along Millaudon canal was clearly more healthy and productive. Similar results are likely to be achieved by a well-designed wetland assimilation project.

Figure 4. Cypress Forest Along Millaudon Canal.

In order to legally discharge effluent to the wetlands Jefferson Parish will have to modify its LDEQ municipal discharge permit. The terms and conditions established in the modified permit will depend on whether the intended discharge site has established water quality and biological standards. Since the park does not have these standards established Jefferson Parish must agree to conduct, during the first year of the discharge permit, a Use Attainability Analysis (UAA). The purpose of the UAA is to evaluate the existing uses of the wetland and gather baseline water quality and ecological data before the effluent is discharged to the site. LDEQ will use the information to develop water quality and biological standards and an appropriate monitoring schedule for the discharge permit. The monitoring carried out by the Parish will be used to verify that the effluent discharge is causing no adverse impact to the wetland. During the first three years of the permit, after the UAA has been conducted and Jefferson Parish is ready to discharge effluent to the wetland site, the LDEQ and the Parish will agree on a compliance schedule which

details interim limits and a monitoring plan. For the final two years of the permit, the final standards established from the UAA will go into effect, and the municipality will be required to show through monitoring that it is in compliance with the terms of its permit.

c) **Remote Sensing Analyses -** NVision was tasked with conducting a Remote Sensing analysis using best available data to determine stressed areas within the bounds of Jean Lafitte Park (Figure 5). Remote sensing is the acquisition and measurement of data or information on some property of an object or material by a recording device not in physical, intimate contact with the feature under surveillance.

Standard Remote Sensing methods were employed in this study. The most recent LandSat 7 data was acquired for a date that was suitable to this study. LandSat 7 is a satellite that acquires moderate resolution imagery of the earth from space. LandSat 7 data resolution is 30 meters, or one pixel covers 30 square meters. The remote sensing technique utilized in this study essentially evaluates vegetative health by comparing plant chlorophyll levels. A more detailed description of the technique can be found in Appendix C.

The results of a Remote Sensing analysis of the Jean Lafitte National Park area are displayed in map format (Exhibits 1, 2 and 3). The analysis was conducted using data from the LandSat 7 Program, acquired in June, 2002 (Exhibit 1) and January, 2003 (Exhibits 2 and 3). The June period presents the best view of the study of the area in a "leaf-on" state however there was significant cloud cover that was not present in the January period. There are several areas that are of a significantly less state of health than surrounding areas in the park. Exhibit 1 has four health/color ranges and Exhibits 2 and 3 have five. Each range in Exhibit 1 is approximately 25% of the relative health with the least healthy beginning at 0% and the most healthy ending at 100%. It follows that in Exhibits 2 and 3 the range for each health/color range is 20%. Exhibit 1 which shows the relative health during the June period does not speak to the overall health of either the flotant marsh or the upland area; rather it speaks to the relative health when compared to other surrounding areas in and near the park.

Water Quality Stations
Parkhead
Mines
Islands
Lafitte Park Boundary

Figure 5. Jean Lafitte Park Area

Using Exhibit 2 and comparing the wooded parts of Areas 3 and 4 against themselves it was found that approximately 2870 acres are ranked as more healthy and approximately 2430 acres are ranked as less healthy.

This area is ideally suited for continued study. The June 2002 image had many areas of cloud cover which prevented an accurate calculation of acreage; however areas under stress were identified.

Comparison

On the field trip to Jean Lafitte National Park many types of sites were visited. Throughout the course of the field trip sites were found that would likely benefit from the treated effluent and sites were found that should not receive the treated effluent. The following table compares the results of some of the general types of site analyses with the results of the Remote Sensing analyses.

Table 4. Field Trip vs. Remote Sensing Conclusion

Site & GPS Number	Description	Field Trip Conclusion	Remote Sensing Conclusion
1 (GPS 2)	Forested wetlands, borrow ponds with floating vegetation	Good Candidate	Good Candidate
5a (GPS 6)	Well drained oak forest with a closed canopy and low light penetration	Poor Candidate	Poor Candidate
5b (GPS 7)	Transition from natural levee to forested wetland	Good Candidate	Good Candidate
5c (GPS 8)	Cypress and Tupelo dominate, herbaceous vegetation is beginning to appear	Good Candidate	Good Candidate
5d (GPS 9)	Cypress and Tupelo with no regeneration and herbaceous understory vegetation	Good Candidate	Good Candidate

4. ROUTING AND REVISED COST ESTIMATES

Preliminary cost estimates were developed in Phase 1 of this study by using the *Westbank Wastewater Treatment Consolidation Study* by Camp Dresser & McKee. Installation costs for open cut methods were used for the entire pipeline run except for areas requiring waterway crossings where jack and bore unit costs were applied. The preliminary estimates are included in Appendix D.

Probable routing corridors leading from the Marrero Treatment Plant and from the Consolidated Plant site at the Hero Canal to the targeted wetlands were inspected to determine whether any unusual field conditions could be identified that would affect the original cost estimates.

Figure 6. V-Shaped Levee and Borrow Pits

With one exception, the discharge force main routings appear to pose no special obstacles for construction. The exception is the routing along the V-Shaped Levee along the northern border of Jean Lafitte National Park in wetland units 3 and 4.

Figure 7. Ames Pumping Station

The V-Shaped Levee has been constructed in a manner that the toe of the levee is immediately adjacent to the Park wetlands. There is little or no room on the south side of that right-of-way (ROW) for pipeline construction. An additional 20 foot ROW will have to be provided by the National Park service in order to construct a pipeline along the wetland side of the levee. Since the Park Service is the main beneficiary of the project, acquisition of the ROW are not anticipated to affect the original cost estimates.

Figure 8. Canal Corridor South of Lapalco

The discharge force main corridor leading from the Marrero Plant site to the wetlands in Unit 2 is wide and clear of obstacles. Therefore, no cost estimate revisions are needed for the Phase 1 costs (Appendix D).

Table 5. Cost Summary for Each Project Alternative

Site	Receiving Acres	Wetland Units	Flow (MGD)	$/MGD	Cost
Individual Plants:					
Harvey	4,900	4,5	14.5	1.8 million	$ 25.9 million
Marrero	6,700	2,3	11.3	0.7 million	$ 7.9 million
Combined Harvey and Marrero	11,600	2,3,4,5	25.8	1.3 million	$ 33.8 million
Harvey Canal Consolidated	11,600	2,3,4,5	40	1.5 million	$ 59.5 million
Hero Consolidated	11,600	2,3,4,5	40	0.9 million	$ 36.1 million

Nitrification

A well nitrified effluent is highly desirable. The primary requirement for nitrification is to raise the sludge age in the treatment process to two to three days. The treatment processe that has been constructed by the Parish is classified as trickling filter-activated sludge. A satisfactory increase in sludge age can be obtained by raising the recirculation ratios, the trickling filter and the activated sludge basins.

5. ENVIRONMENTAL DOCUMENTATION/PUBLIC OUTREACH

This section provides a short summary of the Environmental Report by CH2MHILL. It looks specifically at the Environmental Setting and Environmental Impacts sections. The entire Environmental Report can be found in Appendix E.

Environmental Setting

Jean Lafitte National Park Barataria Preserve is located in the central Barataria Basin. The Basin is an isolated drainage basin between the natural levees of Bayou Lafourche and the Mississippi River. The Preserve encompasses approximately 20,000 acres of hardwood forest, cypress swamp, and fresh water marsh (Bill Huslander, Jean Lafitte National Park Resource Manager, personal communication, April 4, 2003). The Preserve is not a pristine wilderness. The area has been the site of human use for thousands of years. The uses in the last century or so have been the most extensive, including logging, commercial trapping, fishing, hunting, and oil and gas exploration, as well as the development of an extensive canal system, much of which remains in the Park today.

Low relief and several wetland vegetation and soil types characterize the Park. Elevations in the park grade from about 3 feet above sea level on the eastern bottomland ridge and decrease through cypress-tupelo communities to fresh and intermediate marshes near sea level. The soils include highly organic Holocene soil series such as Auemand, Kenner, Lafitte, and Larose (Spicer, 1985). Vegetation includes various types of lowland deciduous hardwoods and cypress-tupelo communities (White et al., 1983).

The swamps and marshes support a complex of different communities, particularly since the marshes "have subsided well below sea level" and are "either intermediate marshes, growing in slightly brackish water, or freshwater marshes." Forty-five species

of freshwater and saltwater fish have been recorded. There are 23 species of amphibians, 22 species of snakes, 240 bird species, and 30 species of mammals.

Environmental Impacts

Within the 21,000+-acre area original identified as a potential discharge area, approximately 7,700 acres were identified as best for wastewater application. These areas are primarily wooded communities with access from a road or a levee that has vehicle access. Areas generally are defined on the east by levees and on the west by canals.

Canals cut the hardwood community distributed in a broad band along the eastern side of the Park and a stream channel runs more than halfway up the lower portion of Area 5 (Exhibit 1). Part of the broadleaf deciduous forest is separated by a levee from the rest of the forest. Emergent marsh dominates the northernmost end of Area 5.

A baseline report on water quality parameters from Maurepas Swamp (Day et al., 2003) and other available data on background water quality in a variety of southern wooded wetlands can be considered to develop general expectations of water quality in the Barataria Preserve sites where the effluent application is proposed.

Day et al. (2003) reported mean and range of water quality parameters for the major bayous and water bodies. These data and the data from several other reports on water quality in southern swamps (Mitsch and Gosselink, 1993; Dortsch, 1996; Ewel and Odum, 1994; Kadlec and Knight, 1996; CH2M HILL, 1985, 1995; and the North American Treatment Wetland Database [NADB], 1993) were used to develop some generalizations about the expected water quality of southern forested wetlands (Appendix E, Table 2). From analysis of these data, it does not appear that the typical water quality in Maurepas Swamp is greatly different from other sites reported. These data also suggest that the values could be considered as a general guide to treatment targets for effluent application in the Barataria Preserve.

Concerns

Treated wastewater applications to wetlands may generate concerns about mosquitoes and other biting insects and the transmission of disease or germs present in the water being applied. Insect pests and disease transmission are not problems in properly designed and managed treatment wetlands.

Conclusions

The risks and benefits of applying treated wastewater to the Park are magnified by the fact that the site under discussion is a national park. Any potential damage or perception of damage caused by an application will be magnified in the public eye. This consideration should lead to a conservative application design, in particular to ensure that no trees are inundated to the point of reduced production or death, and that propagation and growth of young trees is not inhibited by continual flooding. Other effects, such as production of algal scums not typically present, odors, discolored water, or water leaving the Park treatment area that violates standards, also will result in great damage to the important benefits that such an application at this site can have.

This area of Louisiana is subsiding and sea levels are rising. Increased biological production has led to an increased accumulation of wetland soil in Louisiana, as well as in other locations receiving water with increased nutrient levels. In this area, the benefit of increased accumulation cannot be overstated, because it results in a partial balance of the subsidence.

The addition of freshwater will result in less opportunity for intrusion of more saline water, and if properly managed, provide a partial replacement of the annual flooding cycle once provided by the Mississippi River. Although this application will not provide sediments, it will provide some accretion benefits, as indicated above.

The proposed application is a novel approach to the preservation and management of a sensitive and important site. The application of treated wastewater may be the best means of meeting the goals of preserving the ecosystem within the preserve and

simultaneously solving issues associated with the human population in the area. The preliminary analysis indicates that approximately 5,300 acres could be benefited with the Marrero discharge.

A WWTP effluent application to the natural wetlands in the Jean Lafitte National Park/ Barataria Preserve may be beneficial (Day et al., 1999; and Nelson, 2003), but a careful and detailed consideration of the site, the effluent, and the background water quality and expected treatment levels should be fully explored before a decision is finalized.

Agency and Public Outreach

During this study several meetings were held with local representatives of the National Park Service. At these meetings support of the project concept was given. It was emphasized however that a decision of this nature would be made at their headquarters level. Accordingly, this report will be sent to the NPS for their headquarters' review and an area public outreach meeting will be held in the project area after the receipt of NPS headquarters' views on the project. Invited to that public outreach meeting will be representatives from the following: Audubon Council, Sierra Club, League of Women Voters, Orleans Audubon and BTNEP and possibly others.

6. SUMMARY AND CONCLUSIONS

Investigations performed during this project have confirmed that the concept of wetland restoration in West Jefferson Parish, Louisiana using treated municipal wastewater remains viable. A seemingly cost effective first approach was derived and presented. The suggested first approach is to proceed with the evaluation of using treated effluent from an expanded Marrero STP to provide needed nutrients and fresh water to those forested wetlands in Wetland Units 2, 3 and 4 in the Jean Lafitte National Park.

The following consecutive steps are recommended:

1. Have this Phase 2 Report reviewed by the appropriate individuals at Headquarters, Regional and local offices of the National Park Service. Should the NPS staff believe that this is a project that should be reviewed further due to potential benefits to the Park, then schedule a public information meeting to inform local stakeholders of the conceptual plan.
2. The public information meeting should be held in the vicinity of the project with those groups and agencies identified in Section 5 invited to attend. Documentation of discussion points at that meeting should be prepared and distributed.
3. At that point and assuming no fatal flaws are identified the project development should proceed to a third phase consisting of:
    - More precise delineation of those areas in Wetland Units 2, 3 and 4 which would benefit most from nourishment. This would be done through a Use Attainability Analysis.
    - Confirm that those areas are sufficient to receive the anticipated flow from an expanded Marrero plant.
    - Meet with and negotiate the permit limitations for the discharge as may be imposed by the Louisiana Department of Environmental Quality (LDEQ) and/or the U.S. Environmental Protection Agency.

- Obtain a memorandum of understanding between the Parish and the LDEQ and the Parish and the National Park Service as to their agreement to proceed with the project development.

4. Once those work items are completed Phase 4 of the project would entail design of the system components.

There are at least three different sources of participatory federal funding for the project described herein. All of these offer funding from the federal government albeit under different cost share allocations and under different rules and procedures. Each is described briefly below:

1. Aquatic Ecosystem Restoration (206 Program) – This program is implemented by the USACE under authority of Section 206 of the 1996 Water Resources Development Act (WRDA). The intent of the authorization is to allow the Corps to restore degraded ecosystems. It has a cost share allocation of 65 federal / 35 local sponsor. The local sponsor is required to contribute all lands, easements, right-of-way and relocations necessary for the project, which go toward the local match. The maximum federal funding for a project under this authorization is $5 Million, which equates to roughly a $7.5 M project when local funding is included. This is close to the estimated amount necessary for the Marrero only wetlands discharge option at $7.9 M.

   Advantages/Disadvantages – This program represents a reasonable cost share allocation. It might be possible to work this project through the Corps' Section 1135 Program (WRDA 1986) which has a more favorable cost share allocation of 75 /25. To do so however the feasibility study would have to present evidence that the wetlands impact was due to a Corps project. This is possible as many people now believe that one of the primary reasons for coastal land loss in Louisiana is due to the placement of levees for flood control along the Mississippi River under the MR and T Program. The maximum federal funding level under the 1135 Program

is also $5M. Project development under either the 206 or 1135 programs follows the traditional approach for Corps' projects requiring a full feasibility study. From recent experience, project funding under the 206 program appears to be getting tighter. Another possible disadvantage is that it may be difficult to fund a nitrification treatment step at the Marrero plant as 206 funding typically doesn't allow funding of features within the plant itself. Under either program, any operation or maintenance costs associated with the project are not eligible for federal funding and must be borne by the Parish.

2. USEPA Construction Grants Program – This is a program administered through the USEPA to serve as an incentive to construct municipal wastewater treatment works required to meet State and/or Federal water quality standards and improve the water quality in the United States. It is authorized under the Clean Water Act, Public Law 92-500 as amended. An application for a grant for funding through this program must be approved by and submitted through the State's water pollution control agency (LDEQ). To be approved for funding the State must certify that the particular project has priority over other eligible projects in the State. This program essentially operates under Section 202 of the CWA. Federal funding levels are currently 55 % of the project cost. This cost share allocation can be modified under certain circumstances. If the Parish or State could make a defensible claim that the project incorporates innovative or alternative treatment processes then the federal funding level could be increased by 20 %.

   Advantages/Disadvantages – This program does not seem to be funded at high levels as it once was. According to the most recent information from the USEPA web site current funding levels were in the $12 to 17 M range for the last two fiscal years. The average level of financial assistance to a specific project was $3M. From these numbers it appears that this is not a viable option for the Parish to pursue, both in terms of matching percentage and available monies.

3. Environmental Infrastructure Program (219 and 592 Programs) – These are other programs implemented by the USACE. They are done under Section 219 of WRDA 1992 or Section 592 of WRDA 1999. The purpose of the programs is to provide Federal assistance to state and local governments in carrying out water-related infrastructure projects. The cost share allocation for both of these programs is 75 /25 and the local sponsor's share can be made up with in-kind contributions. All operations and maintenance costs are borne by the local sponsor. As with all federal programs, NEPA compliance is required. Written agreements have to be executed between the local sponsor and the USACE prior to any provision of financial assistance from the federal government. Under the 219 program a design agreement or a design and construction agreement between the USACE, NOD and the Parish would be required prior to initiating any technical work such as planning, design or construction assistance. A letter report would be prepared documenting a number of items including the local sponsor's contributions including the requirement to provide land, easements, rights-of-way, relocations and any dredged material disposal area. Under the 592 program the two entities execute a Project Cooperation Agreement (PCA) outlining the terms and conditions of the agreement. The local sponsor can be reimbursed for prior expenditures such as engineering design although only up to a maximum of 6% of the estimated construction cost.

   Under the 219 program any design or engineering assistance is required to be provided by private sources, i.e., the engineering staff of the Corps cannot perform the design work. The procedure for obtaining authorization and funding for either program is as follows. First the local sponsor must arrange to have the Secretary of the Army's office place the project in the official authorization amending WRDA 1992 or WRDA 1999 projects. The USACE NOD can provide sample language for the authorization. This will authorize the project but not provide any actual funding. Funding is obtained by requesting monies to be placed into the annual congressional Energy and Water Bill. Lobbying for this appropriation by the local sponsor's delegation will be required. For the 219 Program typically it requires

several years of appropriation in the Bill, first to cover development of engineering plans and later to fund actual construction.

Advantages / Disadvantages – These programs offer the lowest local cost share allocation on the part of the Parish. Funding under the programs is reportedly easier than under the Corps' 206 or 1135 programs, at least in recent years. Availability of funding though is contingent upon the "political strength" of the local sponsor. The Parish would have to judge this for themselves. From a technical and economic perspective it is apparent that one of these programs would be the preferred mechanism to obtain funding for the wetlands restoration project.

4. Other Options – Less defined but possible funding mechanisms for this project could come from the Breaux Act (CWPRRA) or Louisiana Coastal Area Programs. As this project will provide a direct benefit to the coastal wetlands in Louisiana, it could possibly be funded under either of these programs. The CWPRRA program is an existing program that funds several or more projects per year. The project would be subject to a fairly rigorous technical and environmental benefits review by several different committees. This process could take years to obtain approval for full funding. Another possibility is to obtain funding through the LCA Program if and when it becomes funded at reasonable levels. This is the type of project that could be easily justified under that program. Other possibilities, other than those described herein, would be to seek funding through the Interior Department or National Park Service as their property would receive direct benefits by the project. This option was not investigated as part of this phase 2 study.

EXHIBITS

JUNE 2002

- Water
- Least Healthy
- Less Healthy
- More Healthy
- Most Healthy
- Cloud Mask

LEGEND

JEAN LAFITTE NATIONAL PARK BOUNDARY

EXISTING

PROPOSED

LIMITS OF CANDIDATE WETLANDS AREAS

POSSIBLE ROUTING

EXISTING WATER QUALITY MONITORING STATIONS

PRESENT STP DISCHARGE

AREAS

AREA NO.	MARSH	WOODED	TOTAL
1	3,133	N/A	3,133 AC.
2	2,192	1,620	3,812 AC.
3	7,102	3,117	10,219 AC.
4	N/A	916	916 AC.
5	417	2,011	2,428 AC.

EXHIBIT 1

WALDEMAR S. NELSON AND COMPANY
INCORPORATED
ENGINEERS AND ARCHITECTS
1200 ST. CHARLES AVE. NEW ORLEANS, LA.

WEST BANK OF JEFFERSON PARISH

WETLAND ASSIMILATION STUDY

DATE	SCALE	JOB NO.	DRAWING NO.
5/15/02	N.T.S.	20020109	C1

PLOT DATE: 5/30/02 12:55 P.M. ACAD FILE: 20020109C1.DWG

JUNE 2002

Water
Least Healthy
Less Healthy
More Healthy
Most Healthy
Cloud Mask

LEGEND

JEAN LAFITTE NATIONAL PARK BOUNDARY

EXISTING

PROPOSED

LIMITS OF CANDIDATE WETLANDS AREAS

POSSIBLE ROUTING

EXISTING WATER QUALITY MONITORING STATIONS

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5/15/02	N.T.S.	20020109	C1

PLOT DATE: 5/30/02 12:55 P.M. ACAD FILE: 20020109C1.DWG

LEGEND

EXISTING PARK BOUNDARY

PROPOSED PARK BOUNDARY

LIMITS OF CANDIDATE WETLANDS AREAS

POSSIBLE ROUTING OF NEW SEWER FORCE MAIN

JANUARY 2003 WOODLANDS

UNCLASSIFIED

} MOST HEALTHY = 2867.9 ACRES

} LEAST HEALTHY = 2432.3 ACRES

EXHIBIT 2

WALDEMAR S. NELSON AND COMPANY
INCORPORATED
ENGINEERS AND ARCHITECTS
1200 ST. CHARLES AVE. NEW ORLEANS, LA.

WEST BANK OF JEFFERSON PARISH

WETLAND ASSIMILATION STUDY

DATE	SCALE	JOB NO.	DRAWING NO.
11-16-03	N.T.S.	20020237	C2

PLOT DATE: 11-17-03 ACAD FILE: 20020237C2.DWG

LEGEND

EXISTING PARK BOUNDARY

PROPOSED PARK BOUNDARY

LIMITS OF CANDIDATE WETLANDS AREAS

POSSIBLE ROUTING OF NEW SEWER FORCE MAIN

JANUARY 2003 MARSH

UNCLASSIFIED
WATER
MOST HEALTHY
MORE HEALTHY
HEALTHY
LESS HEALTHY
LEAST HEALTHY

EXHIBIT 3

WALDEMAR S. NELSON AND COMPANY
INCORPORATED
ENGINEERS AND ARCHITECTS
1200 ST. CHARLES AVE. NEW ORLEANS, LA.

WEST BANK OF JEFFERSON PARISH

WETLAND ASSIMILATION STUDY

DATE	SCALE	JOB NO.	DRAWING NO.
11-16-03	N.T.S.	20020237	C3

PLOT DATE: 11-17-03 ACAD FILE: 20020237C3.DWG

APPENDIX A

BACKGROUND

From an ecological perspective, interest in wetlands to assimilate sewage effluent is based on a belief that the free energies of the natural system are both capable of, and efficient at, driving the cycle of production, use, degradation, and reuse (Odum 1978, Breaux and Day 1994). The basic principle underlying wetland wastewater assimilation is that the rate of application must balance the rate of decay or immobilization. The primary mechanisms by which this balance is achieved are physical settling and filtration, chemical precipitation and adsorption, and biological metabolic processes resulting in eventual burial, storage in vegetation, and denitrification (Patrick 1990; Kadlec & Alvord 1989; Conner et al. 1989, Crozier et al. 1996, Boustany et al. 1997, Zhang et al. 2000, Rybczyk et al. 2002).

Effluent discharge generally introduces nutrients such as NO_3, NH_4, PO_4, and organic forms. The nitrogen and phosphorus supplied in the wastewater can be removed in the short-term by plant uptake, in the long-term by peat and sediment accumulation, and permanently by denitrification (Hemond and Benoit 1988). Wetlands that take awhile to move the water through them are best suited for BOD reduction and bacteria dieback. Many pathogenic microorganisms in sewage effluent cannot survive for long periods outside of their host organisms. Protozoa present in shallow waters actively feed on bacteria. The presence of vegetation can also improve the BOD purifying capacity by trapping particulate organic matter and providing sites of attachment for decomposing bacteria.

The ability of wetlands to remove nutrients from inflowing water is primarily dependent on the nutrient concentration and volume of the input water and the area of wetlands. Nutrient uptake is also influenced by temperature and the hydrology of the specific wetland site. The inflow into a wetland is normally expressed as a loading rate that integrates the concentration and volume of the inflow and the area of the receiving wetland. Loading rate is expressed as the amount of nutrient introduced per unit area of wetland per unit time; normally as g N or P /m2/yr.

Nutrient removal is inversely related to loading rate. Richardson and Nichols (1985) reviewed a number of wetland wastewater treatment systems and found a clear relationship between loading rate and nutrient removal efficiency. Nutrient removal efficiency is the percentage of nutrients removed from the overlying water column and retained within the wetland ecosystem or released into the atmosphere. The relationship between nutrient removal efficiency and loading rate is not linear and there is very efficient removal at low loading rates but removal efficiency can decrease rapidly with loading rate.

The curves of Richardson and Nichols (1985) are for wetland sewage treatment systems located in many different parts of the United States. There are a number of studies from Louisiana where loading rates have been reported for coastal wetlands. Breaux and Day (1994) and Day et al. (1999) provided estimates of loading rate and removal efficiencies for forested wetlands near Thibodauax and Breaux Bridge where secondarily treated sewage was being discharged. Nutrient uptake has also been demonstrated for the Caernarvon diversion (Lane et al. 1999) and for the Atchafalaya delta region (Lane et al. 2002) that are similar to the above cited studies.

Richardson (1999) reviewed a number of different wetland assimilation projects and found that when the rate of P loading was about 1 gP/m2/yr, P retention in the wetland was very high. Above a loading rate of 1 g P/m2/yr, retention decreased. Based on this finding, Richardson proposed a one-gram rule of thumb for P loading into wetlands. In most wetland systems, P is retained by plant uptake and attachment to soil particles. In coastal Louisiana, the high rate of subsidence leads to burial being a significant permanent loss pathway. Because of this, subsiding systems in coastal Louisiana can assimilate a higher P loading.

The ultimate ability to remove nutrients over the long run depends on permanent loss pathways. Fortunately, in the Louisiana coastal zone, there are three important pathways for nutrient removal. These include plant uptake, denitrification, and burial.

Uptake and burial are effective for both N and P and other components of treated effluent (such as heavy metals).

Phosphorus in coastal systems is often maintained within a rather narrow concentration range. The highly charged phosphate anion, PO_4^-, is readily sorbed by clay and detrital organic particles at high concentrations, while at lower concentrations PO_4^- is released into the water, thus maintaining moderate ambient concentrations (Jitts 1959). This buffering process occurs in two distinct steps, with adsorption (desorption) of PO_4^- directly onto particle surfaces occurring very rapidly (minutes-days), and then slow (days-months) diffusion of PO_4^- toward the interior of the particles (Froelich 1988). Cyclic aerobic and anaerobic conditions in the top several centimeters of the wetland soil also affect the sorption and release of phosphate (Patrick and Khalid 1974). Sharp et al. (1982) found these sorption-desorption processes provide a buffering mechanism for phosphorus in the Delaware estuary. Madden et al. (1988) showed that total P behaved similarly in Fourleague Bay, Louisiana, with little change in concentration throughout the year.

Burial is the most common mechanism by which phosphorus is permanently lost from the system (Richardson 1985). Flocculation, and subsequent deposition, of dissolved organic and inorganic matter during the mixing of river and sea water is also an important removal mechanism for phosphorus (Sholkovitz 1976). Because of the high relative sea level rise, burial can be very high in coastal Louisiana. DeLaune et al. (1983) reported that P burial in an interior marsh was 0.8 $g\ m^{-2}\ yr^{-1}$. Rybczyk et al. (2002) showed that discharge of treated effluent to a forested wetland in Louisiana increased the rate of accretion and material burial by a factor of about three.

There are many natural wetland systems being used to treat wastewater throughout the United States. There are at least four facilities in Louisiana alone that are currently using natural wetlands to treat municipally treated effluent. They have been shown to

significantly reduce the nitrogen and phosphorous loads. A description of these projects is provided in Appendix B.

References

Boustany, R. G., C. R. Crozier, J. M. Rybczyk, and R. R. Twilley. 1997. Denitrification in a South Louisiana wetland forest receiving treated sewage effluent. Wetlands Ecology and Management 4: 273-283.

Breaux, A.M. and J.W. Day, Jr. 1994. Policy Considerations for Wetland Wastewater Treatment in the Coastal Zone: A Case Study for Louisiana. Coastal Management. 22:285-307.

Conner, W.H., J.W. Day, Jr., and J.D. Bergeron. 1989. A use attainability analysis of wetlands for receiving treated municipal and small industry wastewater: a feasibility study using baseline data from Thibodaux, LA. Center for Wetland Resources, Louisiana State University, Baton Rouge, LA. 78 p.

Crozier, C. R., J. M. Rybczyk, and W. H. Patrick, Jr. 1996. Spatial gradients of dissolved nitrate and nitrous oxide in a wetland forest receiving treated sewage effluent. Proceedings of the Southern Forested Wetlands Ecology and Management Conference. Kathryn Flynn (Ed.) Clemson University, South Carolina. Pages 65 - 68.

Day, J., J. Rybczyk, L. Cardoch, W. Conner, P. Delgado, R. Pratt, and A. Westphal. 1999. pp. 155-166. In L. Rozas, J. Nyman, C. Proffitt, N. Rabalais, D. Reed, and R. Turner (eds.), Recent Research in Coastal Louisiana: Natural System Function and Response to Human Influence. Louisiana Sea Grant College Program, Baton Rouge.

Delaune, R. D., R. H. Baumann, and J. G. Gosselink. 1983. Relationship among vertical accretion, coastal submergence, and erosion in a Louisiana gulf coastal marsh. Journal of Sedimentary Petrology, 53:147-157.

Froelich, P. N. 1988. Kinetic control of dissolved phosphate in natural rivers and estuaries: A primer on the phosphate buffer mechanism. Limnology and Oceanography 4:649-668.

Hemond, H.F. and J. Benoit. 1988. Cumulative impacts on water quality functions of wetlands. Environmental Management 12:639-653.

Jitts, H. R. 1959. The adsorption of phosphate by estuarine bottom deposits. Australian Journal of Marine and Freshwater Research 10:7-21.

Kadlec, R.H. and H. Alvord, Jr. 1989. Mechanisms of water quality improvement in wetla Knight, R.L, T.W. McKim, H.R. Kohl. 1987. Performance of a natural wetland treatment system for wastewater management. Journal of Water Pollution Control Federation, 59(8):746-754.

Lane, R., J. Day, B. Marx, E. Reyes, and P. Kemp. 2002. Seasonal and spatial water quality changes in the outflow plume of the Atchafalaya River, Louisiana, USA. Estuaries. 25: 30-42.

Lane, R.R., J.W. Day, and B. Thibodeaux. 1999. Water quality analysis of a freshwater diversion at Caernarvon, Louisiana. Estuaries 22:327-336.

Madden, C. J., J.W. Day Jr., and J.M. Randall. 1988. Freshwater and marine coupling in estuaries of the Mississippi River deltaic plain. Limnology and Oceanography, 33(4, part 2): 982-1004.

Odum, H.T. 1978. Value of wetlands as domestic ecosystems. Pages 910-930 in H.T. Odum and K.C. Ewel, eds., Cypress Wetlands for Water Management, Recycling, and Conservation. Fourth Annual Report to National Science Foundation and the Rockefeller Foundation.

Patrick, W. H. and R. A. Khalid. 1974. Phosphate release and sorption by soils and sediments: Effect of aerobic and anaerobic conditions. Science 186:53-55.

Richardson, C. J. 1999. The Role of Wetlands in Storage, Release, and Cycling of Phosphorus on the Landscape: A 25-Year Retrospective. pp. 47-68. In: K. R. Reddy, G. A. O'Connor, C. L. Schelske (eds.), Phosphorus Biogeochemistry in Subtropical Ecosystems. Publ. Lewis Publishers. Washington, D. C.

Richardson, C.J. and D.S. Nichols. 1985. Ecological analysis of wastewater management criteria in wetland ecosystems. Pages 351-391 in P.J. Godfrey, E.R. Kaynor, and S. Pelczarski, eds. Ecological considerations in wetlands treatment of municipal wastewaters, Van Nostrand Reinhold Company, NY.

Rybczyk, J., J. Day, and W. Conner. 2002. The impact of wastewater effluent on accretion and decomposition in a subsiding forested wetland. Wetlands. 22: 18-32.

Sharp, J. H., C. H. Culberson, and T. M. Church. 1982. The chemistry of the Delaware estuary. General considerations. Limnology and Oceanography 27:1015-1028.

Sholkovitz, E. R. 1976. Flocculation of dissolved organic and inorganic matter during the mixing of river water and seawater. Geochemica et Cosmochimica Acta 40:831-845.

Zhang, X, S. E. Feagley, J. W. Day, W. H. Conner, I. D. Hesse, J. M. Rybczyk, and W. H. Hudnall. 2000. A water chemistry assessment of wastewater remediation in a natural swamp. Journal of Environmental Quality 29:1960-1968.

APPENDIX B

DESCRIPTION OF SIMILAR PROJECTS

The technical team plans to use published values for wetlands assimilation in this study. The following are short discussions of similar projects reported in the literature.

Carolina Bays

In the late 1970s Horry County South Carolina was experiencing population growth and increased tourism. The county needed to increase their wastewater treatment and disposal facilities. Water treatment and disposal options were evaluated and it was recommended that the county discharge their treated wastewater effluent to four nearby Carolina bays. Carolina bays are land features often filled with wetland vegetation. Four bays totaling 702 acres were used as the sites for the discharge(s). The bays chosen for the treatment complex were not in their natural state due to human impact and were the least environmentally sensitive of all of the bays considered. The system was built for a design flow of 2.5 MGD and an average hydraulic loading rate of 1 inch/week. The final effluent permit limits were BOD_5 monthly average 12 mg/L and TSS monthly average 30 mg/L.

Table B.1 - Operational Water Quality from 1987-1993 in Bear Bay

Parameter	Average WWTP Effluent Inflow Conc. (mg/L)	Average Outflow Concentration (mg/L)
BOD5	13	2
TSS	12	2.5
NO3 + NO2	14	0.2
TN	18	2
TP	4	0.7

The treated effluent was first discharged to the bays in January 1987. Monitoring continued to measure the variations in the water quality and by March 1988 the pilot study had been successfully completed and the program was approved for full scale implementation by EPA. Biological changes have been carefully monitored, with the main observed effect being increased growth of native wetland species. The careful use of Carolina bays for tertiary wastewater treatment facilitates surface water quality management while maintaining the natural character of the bays (USEPA, 1993).

Orlando Easterly

The City of Orlando determined that it needed to construct an advanced wastewater treatment (AWT) plant. An analysis of potential options was completed in 1984 and the conclusion ranked the construction of a wetland for effluent disposal as the number one alternative. The site selected was about 1,640 acres in size and a review of historical data indicated that most of the site was previously part of a wetland system. The original permit issued by the Florida Department of Environmental Protection (FDEP) was for 8 MGD with Orlando's intention to eventually increase their discharge to 20 MGD. An increased capacity of 35 MGD was granted by FDEP in 2001 based on a review of historical site treatment data. The average annual flow recorded in 2001 was 17.9 MGD. The EPA NPDES and FDEP permits require that the wetlands' discharge meet existing background water quality conditions in nearby natural wetlands. Through a study, it was found that the background nitrogen and phosphorous levels are 2.31 mg/L and 0.2 mg/L, respectively. The Orlando Easterly Wetlands project has consistently discharged a water quality that is better than the permit requirements. Operational procedures, such as varying water depths, employed by the project have attempted to minimize nutrient releases while maximizing the ability of the wetland treatment system to remove and store nutrients.

Table B.2 - TN and TP Discharge Concentrations

	Flow (MGD)	TN (mg/L)	TP (mg/L)
FDEP	13.00	2.31	0.2000
1988	10.00	0.84	0.095
1989	13.33	0.92	0.076
1990	13.28	0.93	0.090
1991	12.90	0.80	0.087

To date over 145 bird species have been observed onsite and 10 of these species are state or federally listed and are utilizing the system as part of their habitat. A portion of the project functions as a wilderness park with nature trails and seasonal camping facilities (USEPA, 1993).

Clayton County, GA

The Clayton County Water Authority (CCWA) is currently phasing constructed wetlands as a wastewater treatment technology for several of its facilities. A Master Plan implemented by CCWA, Clayton County Georgia in January 2000 recommended the construction of treatment wetlands to provide for increased flows generated at the new planned wastewater reclamation facilities.

CCWA has recently expanded the Shoal Creek Water Reclamation Facility (WRF) from an initial design capacity of 2.1 to 4.4 MGD. As part of the upgrade, existing effluent management capacity has been expanded with the construction of 55 acres of surface flow (SF = free water surface) treatment wetlands at the Inman Road Site. The treatment wetlands will enhance the water quality of the effluent by adding a polishing step (tertiary process) to the end of the mechanical treatment process found at the Shoal Creek WRF. Initial treatment capacity of the Inman Road Site was initially set at 3.6 MGD by the Georgia EPD.

A larger WRF with a design capacity of 24 MGD is currently under construction as part of the 2000 Master Plan initiatives. This newly constructed WB Casey WRF will utilize treatment wetlands in combination with an existing land application system to optimize overall site treatment capacity. CCWA plans to construct these wetlands in phases. The first phase will contain approximately 55 acres of wetlands and is anticipated to treat in excess of 3.6 MGD. Total wetland treatment capacity at site build out is expected to exceed 15 MGD.

Augusta, Georgia

The City Augusta, currently uses wetlands to provide tertiary treatment capabilities for the J.B. Messerly Wastewater Facility. At site build out, these wetlands are projected to cover approximately 400 acres and treat up to 48 MGD during a peak conditions. Two 30 acre wetland units were constructed in 1997 and used as a pilot system. A second phase of construction was completed in 2001, and the third and final construction phase

was completed in 2002. Total wetland treatment capacity to date is approximately 48 MGD.

Columbia, Missouri

The Columbia Wetlands system is located on the along the Missouri River Flood Plain outside of Columbia, Missouri. Cattails dominate this system which accepts both primary and secondary effluent from a conventional wastewater treatment plant. The current system contains four wetlands with a combined area of approximately 130 acres. Data collected from 1994 to 2000 flow, BOD, TSS, and NH4-N averaged 15.8 MGD, 30 mg/L, 13 mg/L, and 8 mg/L respectively. The system capacity has been recently been upgraded to 20 MGD. The system typically removes greater than 97% of fecal coliforms and fecal streptococcus, 36% of Total Nitrogen, and 4% of Total Phosphorus.

Louisiana

There are at least four facilities in Louisiana that are currently using natural wetlands to treat municipally treated effluent, as shown below in Table B.3. The wetlands have been significantly reducing the nitrogen and phosphorous loads.

Table B.3 - Natural Treatment Wetlands in Coastal Louisiana (Day, 2000)

Site	Treatment Basin (ac)	Flow (MGD)	Nitrogen Loading (g/m^2yr)	Phos. Loading (g/m^2yr)	Nutrient	WWTP Effluent Conc. Discharge (mg/L)	Outlet (mg/L)	% Reduced
Amelia	2500	0.9	9.8 – 19.6	1.1 – 2.1	TKN Total P	2.98 0.73	1 0.06	66 92
Breaux Bridge	3645	1.0	1.87	0.94	NO3-N PO4-P Total P	0.8 1 2.9	<0.1 0.2 0.3	>90 80 87
St. Bernard	3796	0.9	2	0.42	TKN Total P	13.6 3.29	1.4 0.23	89.7 95
Thibodaux	570	4.0	3.1	0.6	NO3-N TKN PO4-P Total P	8.7 2.9 1.9 2.46	<0.1 0.9 0.6 0.85	>90 69 68 66

Thibodaux

In Louisiana, natural wetlands are legally limited to receiving only secondary effluent, and only after approval on a case by case basis. The City of Thibodaux operates a secondary wastewater treatment plant that has the capacity of treating 4 MGD. In March 1992, the city began discharging into Pointe-au-Chene Swamp as part of the treatment process. The study site consists of two almost continuously-flooded forested wetlands (570 ac) within a hydrologically restricted basin separated by a bottomland hardwood ridge. The site treats an average of 4 MGD. At 1600 meters away from the wastewater inlet, mean concentrations were 0.9 mg/L for total N and 0.85 mg/L for total P which achieves tertiary treatment. (Zhang et al., 2000)

Other Louisiana Sites

Breaux Bridge has been discharging its secondarily treated effluent to a 3,645 acre cypress-tupelo swamp for over 50 years. A study was performed and it was found that the flora production increased with the discharging of the nutrient-rich waters into the wetlands (Hesse et al. 1998). The same results were determined in a study conducted at the City of Amelia's discharge site (Day, 2000).

References

Day, J., G. Shaffer, L. Britsch, D. Reed, S. Hawes, and D. Cahoon. 2000. Pattern and processes of land loss in the Mississippi delta : A spatial and temporal analysis of wetland habitat change. Estuaries 23 : 425-438.

Hesse, I., J. Day, and T. Doyle. 1998. Long-term growth enhancement of bald cypress (Taxodium distichum) from municipal waste water application. Environmental Management. 22: 119-127.

USEPA. 1993. Constructed Wetlands for Wastewater Treatment and Wildlife Habitat. EPA832-R-93-005.

Zhang, X, S. E. Feagley, J. W. Day, W. H. Conner, I. D. Hesse, J. M. Rybczyk, and W. H. Hudnall. 2000. A water chemistry assessment of wastewater remediation in a natural swamp. Journal of Environmental Quality 29:1960-1968.

APPENDIX C

Data Analysis Report

Submitted to:

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September 26, 2003

From:

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Requirements

NVision was tasked with conducting a Remote Sensing analysis using best available data to determine stressed areas within the bounds of Lafitte Park (See Figure 1 --Study Area).

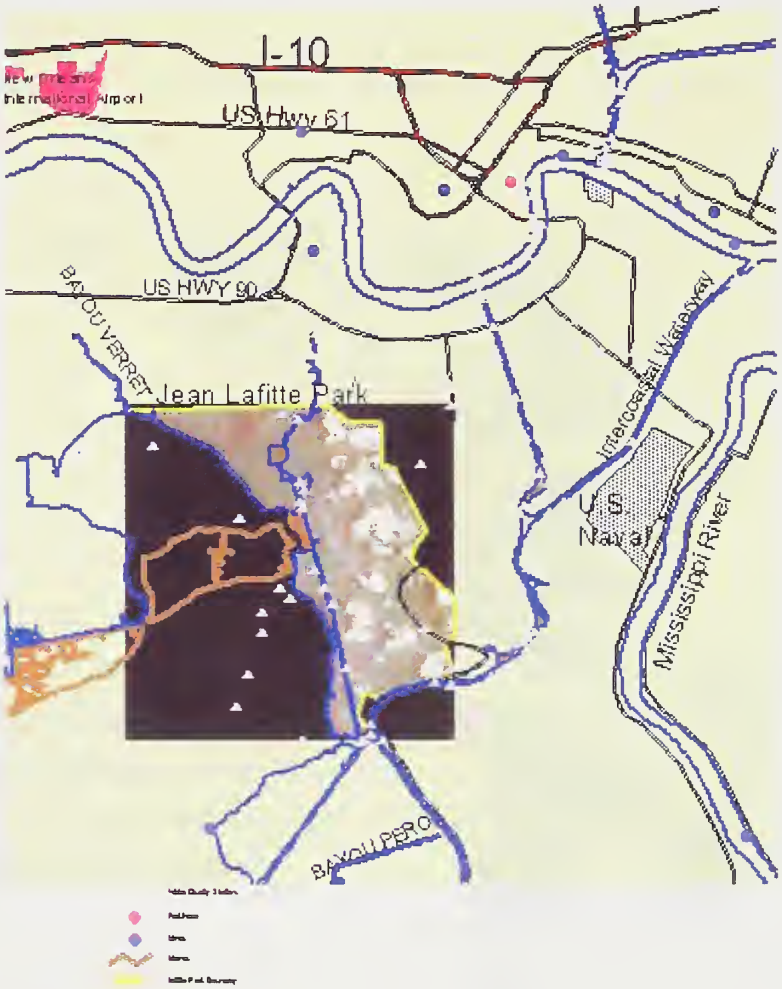

Figure 1 – Study Area, Lafitte Park

The analysis included a field trip to the Park, a mid-project report, Web site, and a final report. This document is the final report. The following url is the Web site that is active as of 9/27/2003.

http://www.nvisionsolutions.com/website/nelson

Userid: nvision
Passwd: nvision

Results

The results of a Remote Sensing analysis of Lafitte part are displayed in map format (See Figure 2 – Stress Areas in Lafitte Park). The analysis was conducted using data from the LandSat 7 Program, acquired in Jan 03, this date period best view of the study of the area in a "leaf-on" state. There are several areas that are of a significantly less state of health than surrounding areas in the park. This study does not speak to the overall health of either the floaton marsh or the upland area; rather it speaks to the relative health when compared to other surrounding areas in and near the park.

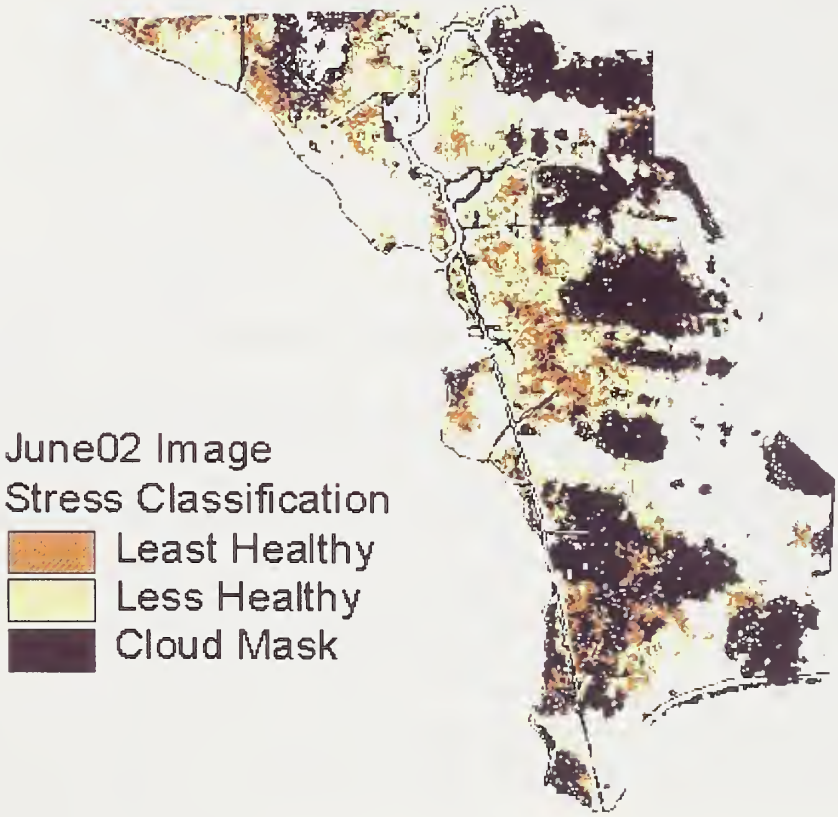

Figure 2 – Stress Areas in Lafitte Park

Methods

Standard Remote Sensing methods were employed in this study. The most recent LandSat 7 data was acquired for a date that was suitable to this study. LandSat 7 data resolution for the multi-spectral bands is 30 meters. Characteristics of the LandSat Data Format are listed in Table 1 – LandSat 7, Characteristics by Band

Characteristics by Band

Band Number	Spectral Range (microns)	Resolution (m)	Characteristics/Uses
1	.45 to .515 - Blue	30	True Color Composite
2	.525 to .605 - Green	30	True Color Composite
3	.63 to .690 - Red	30	True Color Composite
4	.75 to .90 - Near IR	30	Healthy Vegetation
5	1.55 to 1.75 - SWIR	30	Moisture in vegetation/soils
6	10.40 to 12.5 - Thermal IR	60	Temperature of surfaces
7	2.09 to 2.35 - SWIR	30	Moisture in vegetation/soils Mineral content of rocks/soils
8	.52 to .90 - Pan	15	Visible Light

Table 1 – LandSat 7, Characteristics by Band

The multi-spectral analysis conducted went as follows:
First we imported raw LandSat 7 image into a Erdas Imagine file format that included the Red (band 3), Near Infra Red (band 4), Blue (band 1), and Green layers (band 2).
Next a Normalized Differentiated Vegetation Index (NDVI) was created. The NDVI is a ratio of the detected energy in the red and near infrared portions of the electromagnetic spectrum, since they are the most affected by the absorption of chlorophyll in green leafy vegetation. The NDVI can be calculated with the following formula: Where NIR is the energy detected in the near infrared portion of the electromagnetic spectrum and R is the energy detected in the visible red portion of the electromagnetic spectrum. This calculation will produce index values ranging from negative one (-1) to positive one (+1), with values greater than 0.1 representing vegetation with vegetation density increasing as the index gets closer to 1. Negative values are representative of clouds and water, with bare soil and man-made features represented by index values near zero.

$$NDVI = (NIR - R)/(NIR + R)$$

The Normalized Difference Vegetation Index (NDVI) when calculated using LandSat 7 data may be applied as (band 4 – band 3) / (band 4 + band 3) which is a relationship to the proportion of photosynthetically absorbed radiation, calculated from atmospherically corrected reflectance from the visible and near infrared LandSat 7 bands. Where band 3 is the reflectance in the visible wavelengths (0.63-0.69 um) and band 4 is the reflectance in the reflective infrared wavelengths (0.75- .90 um). The principle behind this is that band 3 is in a part of the spectrum where chlorophyll causes considerable absorption of incoming radiation, and the band 4 is in a spectral region where spongy mesophyll leaf structure leads to considerable reflectance.

The NDVI was then classified into 12 equal area classifications. Meaning that for the study area there was twelve areas each containing the same number of grouped cells. These 12 classes were then grouped into 4 ranges of relative health, poorest to healthiest, water, and a cloud mask. (See Figure 3 – Classified NDVI) The cloud mask was required due to "pop corn" cloud formations present in the image and typical of spring satellite data collected in this region. The June image was the only available image until late summer where vegetative senescence would have been a factor.

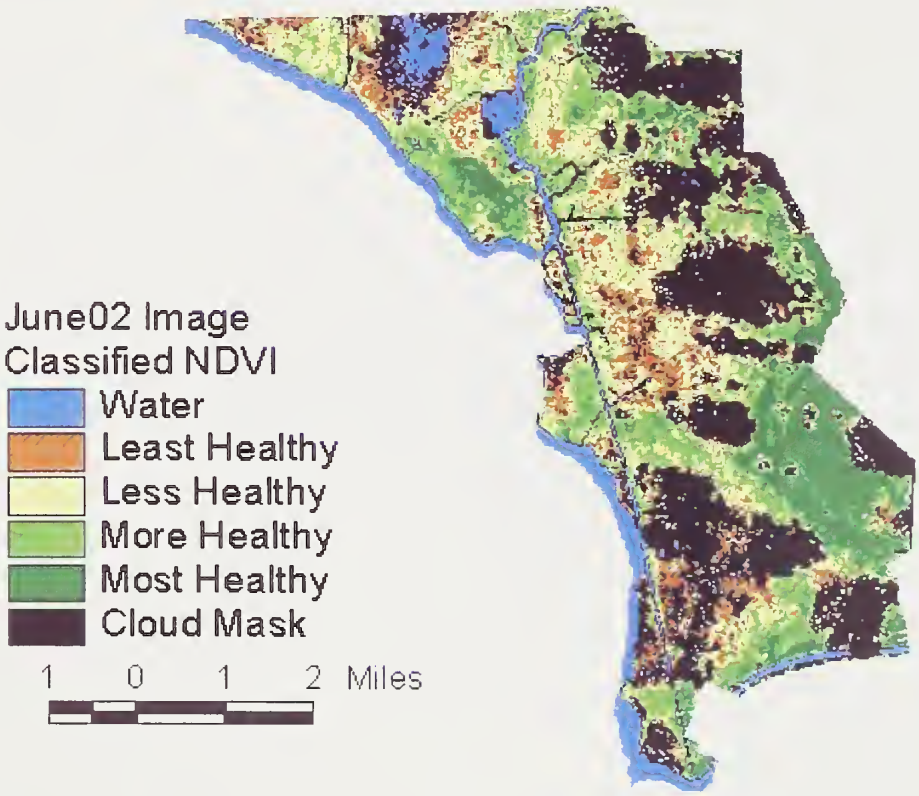

Figure 3 – Classified NDVI

Recommendations

This area is ideally suited for continued study. A more advanced analysis of the region might include signature files for arboreal speciation and a distinction between upland, flooded timber, and marsh areas. Moreover, it seems logical and important that a base-line study be conducted prior to or during implementation to establish metrics by which to determine the degree of success implementation is likely to have. This study would

prove invaluable not only to this area, but to other areas where similar efforts might be employed.

Craig A. Harvey

For questions related to the technical details of this report, please contact: Craig Harvey, CIO, NVision Solutions, Inc. (228) 688-2205

APPENDIX D

ESTIMATED COSTS FOR PROJECT IMPLEMENTATION

Preliminary cost estimates were developed for each alternative under evaluation in this study. In this Phase 1 study, it was assumed that no additional treatment would be required at the plant for a wetlands discharge alternative. The cost analyses then became one of just determining the cost of transporting the flow from alternative locations to the nearest candidate wetland location and then distributing the flow throughout that wetland. Only pipe installation costs were included in these analyses as it was further assumed that the existing pump stations at the individual plant locations could convey the flow to the wetland. It was further assumed that in those alternatives involving a consolidated plant location, that the pump station built to convey that flow to the River would also be used to convey it to the candidate wetlands. Pipeline routing was assumed to occur along established linear corridors either defined in Jefferson Parish documents for consolidated plant locations or along power line or street right of ways. For the preliminary estimates in this study, pipeline installation unit cost estimates for different sizes of pipe were obtained from the *Westbank Wastewater Treatment Consolidation Study* by Camp Dresser & McKee. Installation costs for open cut methods were used for the entire pipeline run except for areas requiring waterway crossings where jack and bore unit costs were applied.

The alternatives evaluated included the following:

1. Individual discharge from the existing Harvey STP to wetland unit 5
2. Individual discharge from the existing Marrerro STP to wetland unit 3
3. Individual discharge from the existing Bridge City STP to wetland unit 2
4. Consolidated discharge from the Harvey Canal site to wetland unit 5
5. Consolidated discharge from the Bridge City site to wetland unit 2
6. Consolidated discharge from the Landfill Site to wetland unit 2
7. Consolidated discharge from the Hero site to wetland unit 5

Note: The receiving wetland unit depicted in the alternatives list above is only the initial receiving wetland unit. Once inside the wetland unit, it is anticipated that the

pipelines would run along linear features (levees or roads). The pipes would be sequentially stepped down in size as flows were diverted for wetland assimilation.

Following are descriptions and costs of each of the above alternatives.

1. Harvey STP - In order to run a force main from the existing Harvey plant to the wetlands unit 5 both the open cut and jack and bore technique are necessary. The pipe that will run under the Harvey Canal will have to be directionally drilled using the jack and bore method. Harvey currently uses a 48" line to discharge their effluent to the river so that pipe size was used to calculate discharge to the wetlands. The pipe will be run from the Harvey plant to unit 5 and then into unit 4. After entering the wetlands the 48 " diameter pipe will be sequentially stepped down to a 12 " diameter pipe. Estimated costs for this alternative are shown in Table D.1.

2. Marrerro STP - Marrero currently uses a 48" line to discharge effluent to the River. The calculations for Marrero were made the same as they were for Harvey. The pipe would be run from the Marrero plant down to area 3 before discharge begins. The piping that will run through the wetlands starts out at 48" diameter and graduates down to 8". Estimated costs for this alternative are shown in Table D.1.

3. Bridge City STP - The Bridge City plant is currently using a 36" pipe to discharge effluent to the River. To discharge to the marsh the pipe would be run from the plant to area 2 which would accommodate the flow from the plant. The piping that will run through the wetlands begins at 36" diameter and graduates down to 8". The estimated cost for this alternative is shown in Table D.1.

The estimated total to convert all three existing plants to a wetland discharge is $52 million.

Another possible option is to dispose of the effluent from Harvey and Marrero into the wetlands and Bridge City would continue discharging into the Mississippi River. This option would cost $34 million as shown in Table D.1.

Table D.1 Estimated Costs for Existing STP Discharges to Wetlands

Site Location	Existing/Future Pipeline Size Going to the Wetlands	Distance to Wetlands (ft)	Total Cost per L.F.	Total Cost
Harvey STP				
- Developed Area	48"	21,918	$ 422.00	$ 9,249,396
- Waterway Crossing	48"	6,582	$ 1,174.00	$ 7,727,268
- Wetlands	48"	6,363	$ 242.00	$ 1,539,846
	42"	7,560	$ 196.00	$ 1,481,760
	36"	4,000	$ 140.00	$ 560,000
	30"	4,000	$ 120.00	$ 480,000
	24"	3,000	$ 110.00	$ 330,000
	18"	1,000	$ 100.00	$ 100,000
	15"	1,000	$ 60.00	$ 60,000
	12"	1,000	$ 40.00	$ 40,000
		Harvey Total	--	**$ 21,568,270**
Marrero STP				
- Developed Area	48"	3,635	$ 422.00	$ 1,533,970
- Wetlands	48"	8,730	$ 242.00	$ 2,112,660
	42"	2,666	$ 196.00	$ 522,536
	36"	7,000	$ 140.00	$ 980,000
	30"	5,000	$ 120.00	$ 600,000
	24"	4,000	$ 110.00	$ 440,000
	18"	2,000	$ 100.00	$ 200,000
	15"	1,000	$ 60.00	$ 60,000
	12"	2,000	$ 40.00	$ 80,000
	8"	2,000	$ 30.00	$ 60,000
		Marrero Total	--	**$ 6,589,166**
Bridge City STP				
- Developed Area	36"	29,648	$ 336.00	$ 9,961,728
- Waterway Crossing	36"	2,500	$ 874.00	$ 2,185,000
- Wetlands	36"	6,363	$ 140.00	$ 890,820
	30"	2,629	$ 120.00	$ 315,480
	24"	9,000	$ 110.00	$ 990,000
	18"	2,000	$ 100.00	$ 200,000
	15"	4,000	$ 60.00	$ 240,000
	12"	4,000	$ 40.00	$ 160,000
	8"	2,000	$ 30.00	$ 60,000
		B. City Total	--	**$ 15,003,028**
- 20% Contingency for all plants				**$ 8,632,093**
			Total for All Plants	**$ 51,792,577**

(Continued from previous page)				
Cost of Only Harvey and Marrero Discharging to the Wetlands				
- Harvey - Marrero				$ 21,568,270 $ 6,589,166
- 20% Contingency for Harvey and Marrero				**$ 5,631,487**
				$ 33,788,923

4. Harvey Canal Consolidated Site - One of the locations under consideration for a consolidated plant is located south of the Harvey plant called the Harvey Canal Site. Similar to the Harvey STP both open cut and jack and bore techniques will be necessary to run the force main. A 72" pipe will be necessary to move the effluent from the plant to the wetlands. The pipe discharging into the wetlands would be run along areas 2, 3, 4 and 5. The calculations were performed based on a water velocity in the distribution system of 4 fps. It would begin distribution at 72" and then graduate down to 8" toward the end. It is estimated that the cost of the piping from the Harvey Canal consolidated plant would be $60 million as shown in Table D.2.

Table D.2 - Consolidated Plant at Harvey Canal Site

Harvey Canal Consolidated Plant Site	Existing/Future Pipeline Size Going to the Wetlands	Distance to Wetlands (ft)	Total Cost per L.F.	Total Cost
- Developed Area	72"	9,090	$ 751.00	$ 6,826,590
- Waterway Crossing	72"	5,180	$ 2,718.00	$ 14,079,240
- Wetlands	72"	17,755	$ 434.00	$ 7,705,670
	66"	8,000	$ 390.00	$ 3,120,000
	60"	14,000	$ 362.00	$ 5,068,000
	54"	14,000	$ 305.00	$ 4,270,000
	48"	12,000	$ 242.00	$ 2,904,000
	42"	10,000	$ 196.00	$ 1,960,000
	36"	8,000	$ 140.00	$ 1,120,000
	30"	8,070	$ 120.00	$ 968,400
	24"	7,000	$ 110.00	$ 770,000
	18"	4,000	$ 100.00	$ 400,000
	15"	3,000	$ 60.00	$ 180,000
	12"	4,000	$ 40.00	$ 160,000
	8"	2,000	$ 30.00	$ 60,000
- 20% Contingency				$ 9,918,380
		Total		**$ 59,510,280**

5. Bridge City Consolidated Site - Another consolidated site under consideration is just southeast of the operational Bridge City STP and is called the Avondale Site. Only open cut is necessary for the Avondale Site. A 72" force main will be run from the site to wetland unit 2. The distribution system discharging into the wetlands will run along the perimeter of areas 2, 3, 4, and 5. The calculations were performed based on a water velocity in the distribution system of 4 fps. The system will begin at 72" and then graduate down to 8". It is estimated that the cost of the piping from the Avondale consolidated plant would be $68 million. (See Table D.3)

Table D.3 – Consolidated Plant at Avondale Site

Avondale Consolidated Plant Site	Existing/Future Pipeline Size Going to the Wetlands	Distance to Wetlands (ft)	Total Cost per L.F.	Total Cost
- Developed Area	72"	26,384	$ 751.00	$ 19,814,384
- Waterway Crossing	72"	2,500	$ 2,718.00	$ 6,795,000
- Wetlands	72"	17,775	$ 434.00	$ 7,714,350
	66"	16,000	$ 390.00	$ 6,240,000
	60"	16,000	$ 362.00	$ 5,792,000
	54"	12,000	$ 305.00	$ 3,660,000
	48"	4,000	$ 242.00	$ 968,000
	42"	10,000	$ 196.00	$ 1,960,000
	36"	8,000	$ 140.00	$ 1,120,000
	30"	8,000	$ 120.00	$ 960,000
	24"	7,000	$ 110.00	$ 770,000
	18"	4,000	$ 100.00	$ 400,000
	15"	3,000	$ 60.00	$ 180,000
	12"	4,000	$ 40.00	$ 160,000
	8"	2,000	$ 30.00	$ 60,000
- 20% Contingency				$ 11,318,747
		Total		**$ 67,912,481**

6. Landfill Consolidated Site - The Landfill Site, located northwest of the Avondale Site, is another location under consideration. Only open cut is necessary for the Landfill Site. A 72" force main will be run from the site to area 2. The distribution system discharging into the wetlands will run along the perimeter of areas 2, 3, 4, and 5. The calculations were performed based on a water velocity in the distribution system of 4 fps. The distribution system will begin at 72" and then

graduate down to 8". It is estimated that the cost of the piping from the Landfill consolidated plant would be $86 million (See Table D.4).

Table D.4 – Landfill Consolidated Site

Landfill Consolidated Plant Site	Existing/Future Pipeline Size Going to the Wetlands	Distance to Wetlands (ft)	Total Cost per L.F.	Total Cost
- Developed Area	72"	46,176	$ 751.00	$ 34,678,176
- Waterway Crossing	72"	2,500	$ 2,718.00	$ 6,795,000
- Wetlands	72"	17,775	$ 434.00	$ 7,714,350
	66"	16,000	$ 390.00	$ 6,240,000
	60"	16,000	$ 362.00	$ 5,792,000
	54"	12,000	$ 305.00	$ 3,660,000
	48"	4,000	$ 242.00	$ 968,000
	42"	10,000	$ 196.00	$ 1,960,000
	36"	8,000	$ 140.00	$ 1,120,000
	30"	8,000	$ 120.00	$ 960,000
	24"	7,000	$ 110.00	$ 770,000
	18"	4,000	$ 100.00	$ 400,000
	15"	3,000	$ 60.00	$ 180,000
	12"	4,000	$ 40.00	$ 160,000
	8"	2,000	$ 30.00	$ 60,000
- 20% Contingency				$ 14,291,505
		Total		**$ 85,749,031**

7. Hero Consolidated Site - The Hero site is another consolidated plant location under consideration. It is located just north of area 5. Only open cut is necessary for the Hero Site. A 72" force main will be run from the site to area 2. The distribution system discharging into the wetlands will run along the perimeter of areas 2, 3, 4, and 5. The calculations were performed based on a water velocity in the distribution system of 4 fps. The distribution system will begin at 72" and then graduate down to 8". It is estimated that the cost of the piping from the Hero consolidated plant would be $36 million (Table D.5).

Table D.5 – Hero Consolidated Plant Site

Hero Consolidated Plant Site	Existing/Future Pipeline Size Going to the Wetlands	Distance to Wetlands (ft)	Total Cost per L.F.	Total Cost
- Developed Area	72"	1,900	$ 751.00	$ 1,426,900
- Wetlands	72"	17,755	$ 434.00	$ 7,705,670
	66"	8,000	$ 390.00	$ 3,120,000
	60"	14,000	$ 362.00	$ 5,068,000
	54"	14,000	$ 305.00	$ 4,270,000
	48"	12,000	$ 242.00	$ 2,904,000
	42"	10,000	$ 196.00	$ 1,960,000
	36"	8,000	$ 140.00	$ 1,120,000
	30"	8,070	$ 120.00	$ 968,400
	24"	7,000	$ 110.00	$ 770,000
	18"	4,000	$ 100.00	$ 400,000
	15"	3,000	$ 60.00	$ 180,000
	12"	4,000	$ 40.00	$ 160,000
	8"	2,000	$ 30.00	$ 60,000
- 20% Contingency				$ 6,022,594
		Total		**$ 36,135,564**

The following table D.6 lists the costs for each of the alternatives on a per MGD basis. Consolidated plants were calculated on a flow of 40 MGD.

Table D.6 – Unit Costs for Each Alternative

Site	Receiving Acres	Units	Flow (MGD)	$/MGD
All three upgraded:	11,600	2,3,4,5	30.3	1.7 million
Harvey	4,900	4,5	14.5	1.8 million
Marrero	6,700	2,3	11.3	0.7 million
Bridge City	6,700	2,3	4.9	3.7 million
Harvey and Marrero	11,600	2,3,4,5	25.8	1.3 million
Harvey Canal	11,600	2,3,4,5	40	1.5 million
Avondale	11,600	2,3,4,5	40	1.7 million
Landfill	11,600	2,3,4,5	40	2.1 million
Hero	11,600	2,3,4,5	40	0.9 million

The costs in Table D.6 show that many of the alternatives posed are feasible and in the same $/MGD range.

APPENDIX E

Environmental Report–Application of Treated Wastewater to the Jean Lafitte National Park/Barataria Preserve Area

June 2003

Prepared by

CH2M HILL
New Orleans, Louisiana

Prepared for

Waldemar S. Nelson and Company, INC.;
Under Contract to the U.S. Army Corps of Engineers
New Orleans District

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Environmental Report–Application of Treated Wastewater to the Jean Lafitte National Park/Barataria Preserve Area

Introduction

Jefferson Parish and the U.S. Army Corps of Engineers, New Orleans District, have conducted a joint study to define the technical and cost feasibility of applying highly treated wastewater to areas of the Jean Lafitte National Park as a wetlands restoration measure, potentially including areas proposed for acquisition in the near future. The goal of this report is to provide an assessment of the potential beneficial and adverse impacts to the natural environment of the Park associated with the introduction of treated wastewater.

The objectives of this report are to:

- Provide a description of the environmental setting of the park, including the basic features of the Park lands, the vegetation communities and their relative importance, and a general summary of the current condition of the Park lands.
- Develop a description of the appropriate application of treated wastewater for the purposes of wetland restoration on this site, including hydrologic and chemical issues associated with the effort.
- Describe the potential benefits and risks of the application.
- Develop a summary set of recommendations concerning wastewater application that will provide the greatest benefit with the least risk based on the level of analysis presented in this report.

This report is organized to address project objectives as follows:

- An overview is provided of the broad environmental conditions in the Mississippi River Delta Region that underlie the current circumstances in the Park. This part of the report is entitled "Environmental Setting" and includes descriptions of vegetative habitat types and fish and wildlife resources found within the project area.
- The report then presents the environmental impacts associated with project implementation. Included in the section are likely wastewater treatment discharge parameters, presented based on data provided in Nelson (2003), proposed application methods, and expected wetland removal. This section assumes optimal conditions for nutrient uptake and discusses any issues associated with meeting those optimal conditions on this site.
- The discussion of potential benefits and risks follows the analysis of the proposed application, and will be based on the recent history of wastewater applications to wetlands and a comparison of the optimal conditions to the conditions on this site.

- Finally, a summary set of recommendations concerning the application of wastewater to the site will be presented.

Environmental Setting

Jean Lafitte National Park Barataria Preserve is located in the central Barataria Basin, 25 miles inland from the Gulf of Mexico and immediately south of the New Orleans metropolitan area (Figure 1). The Barataria Basin is an isolated drainage basin between the natural levees of Bayou Lafourche and the Mississippi River. Some 2,500 years ago, the river began building a delta in the area that is now New Orleans. This delta had at least three main channels, and one of them, Bayou des Families, deposited the sediments that underlay the present-day Preserve area. The Preserve encompasses approximately 20,000 acres of hardwood forest, cypress swamp, and fresh water marsh (Bill Huslander, Jean Lafitte National Park Resource Manager, personal communication, April 4, 2003).

The Preserve is not a pristine wilderness. The area has been the site of human use for thousands of years. The uses in the last century or so have been the most extensive, including logging, commercial trapping, fishing, hunting, and oil and gas exploration, as well as the development of an extensive canal system, much of which remains in the Park today.

Vegetative Habitat Types

Low relief and several wetland vegetation and soil types characterize the Park. Elevations in the park grade from about 3 feet above sea level on the eastern bottomland ridge and decrease through cypress-tupelo communities to fresh and intermediate marshes near sea level. The soils include highly organic Holocene soil series such as Auemand, Kenner, Lafitte, and Larose (Spicer, 1985). Vegetation includes various types of lowland deciduous hardwoods and cypress-tupelo communities (White et al., 1983). Young disturbed canal spoil banks support *Salix nigra, Myrica cerifera, lva foitescens, Phragmites australis,* and an introduced species, *Sapium sebifenim.* Older spoil banks (more than 50 years old) support species resembling those found on natural levees of coastal Louisiana (White et al., 1983).

Common trees are *Taxodium distichum (Bald Cypress), Celtis laevigata, Quercus virginiana, Liquidambar strvaciflua, Acer rubrum, Quercus nigra,* and *Salix nigra* (White et al., 1983. The intermediate marsh is characterized by the presence of *Spartina patens, Phragmites australis,* and a mix of freshwater plants. The freshwater marsh is dominated by *Sagittaria lancifolia, Panicum hemitomum L, Polvgonum punctatum,* and *Alternathera philoxeroides.*

Part of the Barataria Preserve area has been mapped for the National Wetlands Inventory (NWI) (Figure 2). The western portion of the park not shown in Figure 2 has not been mapped and the left (western) edge of Figure 2 is the edge of the published vegetation mapping. However, the unmapped area is almost all emergent marsh and a complete vegetation map of the Park is not critical to the issues evaluated in this report. The community types shown in Figure 2 are composite sets of similar communities mapped by the National Wetlands Inventory at a greater level of detail, according to Cowardin et al. (1979). The vegetation types that were combined to produce the simplified map shown here are described in Table 1.

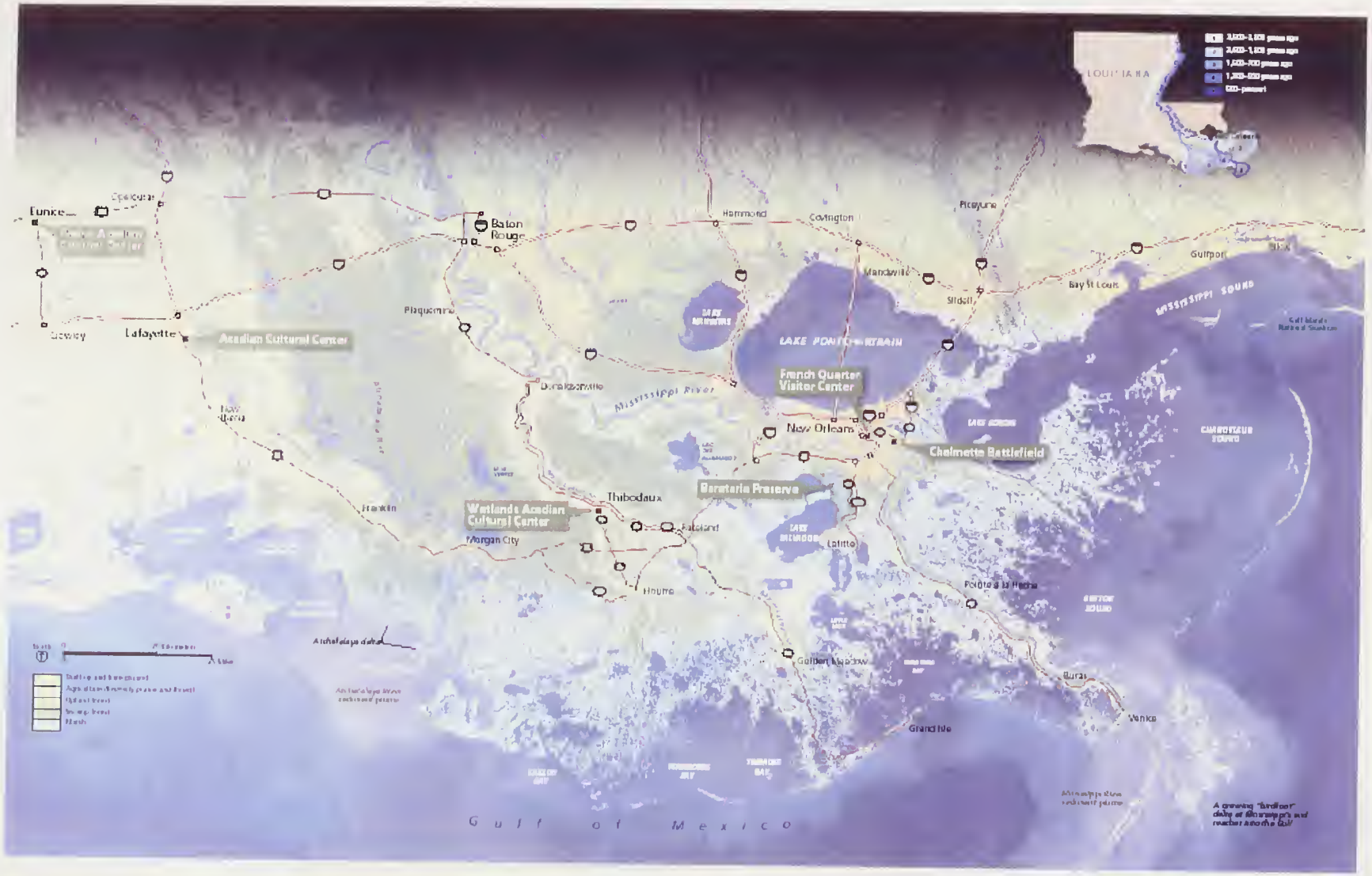

FIGURE 1
Location of Barataria Preserve/Jean Lafitte National Park near New Orleans, Louisiana
Figure from: http://www.nps.gov/carto/JELA.html Park Regional Map.

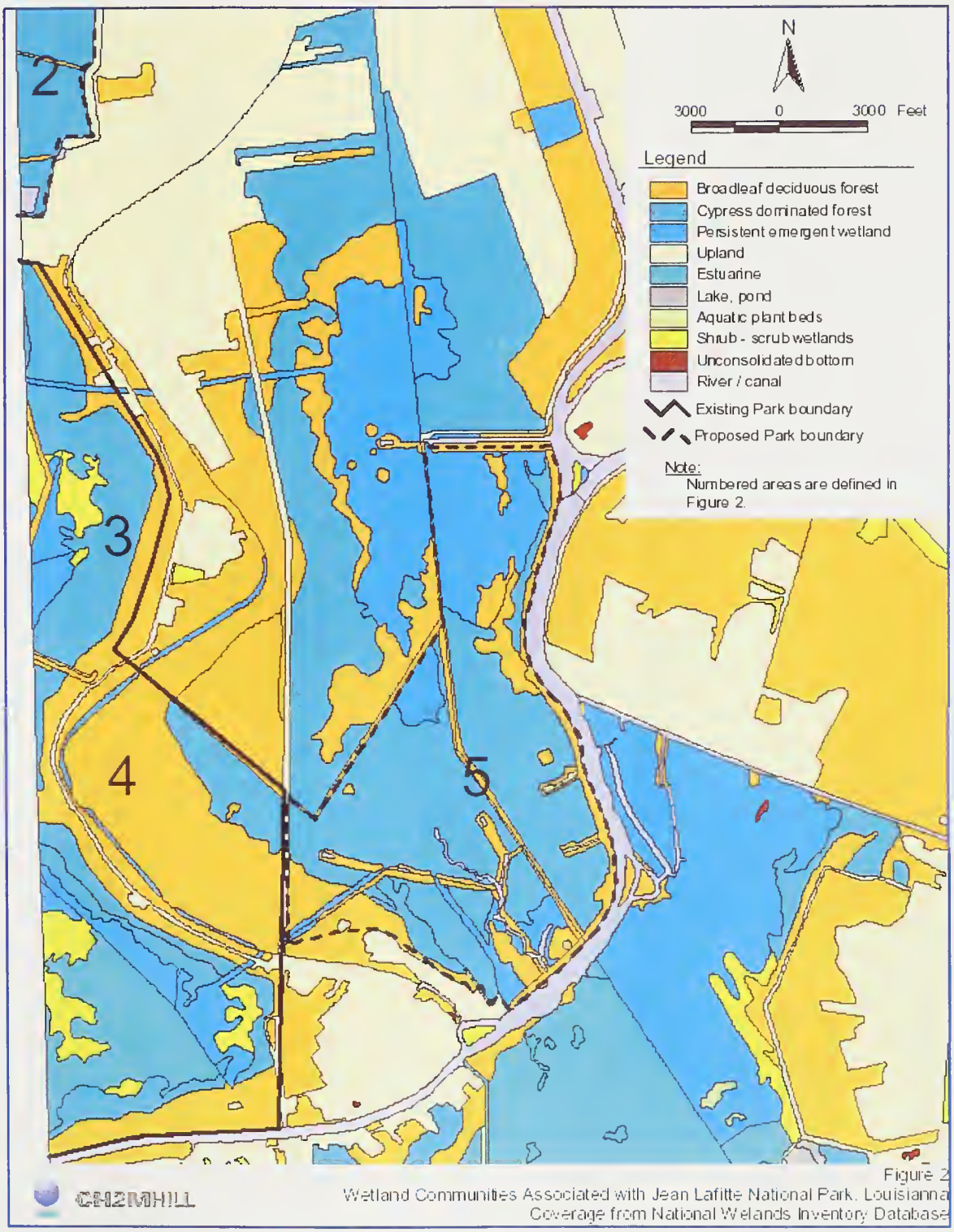

FIGURE 2

Wetland Communities Associated with the Eastern Side of Jean Lafitte National Park/Barataria Preserve, Louisiana Coverage was developed from the National Wetlands Inventory database. Table 1 describes wetland types combined to create the community coverages shown here.

TABLE 1
Wetland Community Composition of the Community Types Identified in Figure 2 *

Figure 2 Community Description	USFWS Community Classifications Included	Cowardin Classification Descriptors
Broadleaf Deciduous Forest *A swamp with a mix of trees dominated by species other than cypress*	PFO1A PFO1As PFO1Ad PFO1Adh PFO1C PFO1/2f PFO1/2Cs PFO1/2Cdh PFO1/2Fdh	P = Palustrine–nontidal wetlands dominated by trees, shrubs, persistent emergents, emergent mosses and lichens, and all such wetlands that occur in tidal areas where salinity is less than 0.5 parts per thousand FO = Forest Wetland 1 = Deciduous broadleaf Forested Wetland 2= Needle leafed deciduous Forested Wetland C = Seasonally Flooded F = Semipermanently Flooded d = Partially Drained/Ditched f = Farmed s = Spoil
Cypress Dominated Forest *A cypress dominated swamp but including other species of tree*	PFO 2/1 PFO2/1C PFO2/1Fdh PFO2/1f PFO2f PFO2C	See above
Persistent emergent wetland *Erect, rooted, herbaceous hydrophytes excluding mosses and lichens. Indicates permanent emergent marsh vegetation–a "typical" marsh*	PEM1	P = Persistent EM = Emergent Marsh 1 = seasonally Flooded
Upland	UP	Upland Sites–without wetland soils
Estuarine *Tidal habitats and tidal wetlands, brackish (dilute) to full salt water in nature at least occasionally diluted by freshwater runoff from land. In this case, the water is almost always less salty than full seawater and greater than 0.5 parts per thousand total salts*	E	
Lake, Pond *Limnetic–Fresh, open water ponded environments*	L	

TABLE 1
Wetland Community Composition of the Community Types Identified in Figure 2 *

Figure 2 Community Description	USFWS Community Classifications Included	Cowardin Classification Descriptors
Aquatic Plant Beds	PAB	
Wetlands dominated by plants growing principally on or below the surface of the water		
Unconsolidated Bottom	PUB	Open water areas that have a soft bottom
River / Canal	R	

Notes:
* The communities named in Figure 2 are composites of specific community types identified using the Cowardin et al. (1979) wetland community classification scheme.

There were relatively few pure Bald Cypress stands identified in the original NWI map; mixed stands of Bald Cypress and tupelo with lesser dominance of other woody species dominated the wooded acreage. The site is completely diked on the eastern edge, and Area 5 and part of Area 2 are, in fact, surrounded by levees. Levees and spoil banks adjacent to canals within the Preserve create additional hydrologic barriers.

Bill Huslander, a Resource Manager for the Jean Lafitte National Park, indicated that the National Park Service currently estimates that there are about 14,000 wooded acres in the preserve. However, he believes that a significant portion of the hardwood acreage is associated with patches of swamp mixed in the larger emergent marsh area. He stated that a wetland mapping effort is underway to complete the work already published (personal communication, April 4, 2003).

Areas of the Park initially identified (Nelson, 2003) as a potential for hydration (areas in white in Figure 2) included most of the Preserve and areas immediately adjacent to the Preserve currently proposed for purchase (Figure 1 areas with dotted line borders, a total of 5,206 acres). The Preserve is the area in Figure 2 bounded in solid blue lines, including areas on the eastern shore of Lake Salvador that were not included in the potential hydration area.

Fish and Wildlife Resources

An excellent summary of the wildlife (fish, birds, and mammals) in many of the areas under consideration for wastewater application is found in the Jean Lafite Barataria Preserve Boundary Study/Environmental Assessment (U.S. Department of the Interior, 1998). This short wildlife summary is drawn from that report, unless otherwise noted.

The swamps and marshes support a complex of different communities, particularly since the marshes "have subsided well below sea level" and are "either intermediate marshes, growing in slightly brackish water, or freshwater marshes." Forty-five species of freshwater and saltwater fish have been recorded, including those of recreational interest to freshwater and saltwater fishermen (largemouth bass, catfish, sunfish, redfish, and spotted seatrout). There are 23 species of amphibians, 22 species of snakes, 240 bird species, and 30 species of mammals. There are a number of wading bird rookeries within the Preserve. Neotropical (North American to as far as South America) migrating birds include 115 species. Among those birds, the site is used both as a resting site and as a winter home.

There are several listed (threatened and endangered) bird species found on the site. They are primarily migratory and relatively uncommon. The bald eagle and arctic peregrine falcon are among those listed species that use the site for over-wintering. The american alligator is a common full-time inhabitant of the Preserve. Several candidate species for listing, including the resident alligator snapping turtles and several migrant species, also have been recorded. A number of state bird species of special concern have been recorded, but with one exception, Cooper's Hawk, none of those species is known or presumed to breed within the Preserve.

The Barataria Preserve is considered a "hot spot" for birding in Louisiana (http://www.camacdonald.com/birding/uslousiana.htm) and the National Park Service maintains a variety of trails, access points, and educational programs to encourage the use of the site for wildlife spotting, among other activities.

Environmental Impacts

Wetland Areas Best Suited for Hydration

Within the 21,000+-acre area original identified as a potential discharge area, approximately 5,906 acres were identified as best for wastewater application. These areas are primarily wooded communities (PFO 2/1 or PFO 1/2) with access from a road or a levee that has vehicle access. Areas generally are defined on the east by levees and on the west by canals.

Canals (Figures 2 and 3) cut the hardwood community distributed in a broad band along the eastern side of the Park and a stream channel runs more than halfway up the lower portion of Area 5. Part of the broadleaf deciduous forest is separated by a levee (shown as a band of upland vegetation that runs generally from north to south within large extent of broadleaf deciduous forest in Figure 2) from the rest of the forest. Emergent marsh dominates the northernmost end of Area 5 (Figure 2).

The maximum use of the site can only be achieved by filling the minor canals and distributing the effluent discharge points along the border of the area and away from the existing canals. Otherwise, much of the applied water will move directly into the canal system and move out into Lake Salvador. Assuming that the larger canals are not plugged, the current distribution of canals in this zone suggests that not all of that area can be hydrated. Figure 4 shows approximate areas where treatment might be expected without filling any major canals:

- In Area 2, there are an estimated 2,325 acres of wooded wetlands. Figure 2 shows those areas that potentially could receive effluent before the flow path intercepted a canal. A large portion of the total wooded area would not receive water.
- Area 3 is divided into three small sections by canals and confined on the west by canals, as well.
- Application to Area 4 can potentially result in treatment to the entire area inside the canal that provides the curved western border (Figure 4). Wetlands beyond that canal in Area 4 and those adjacent wooded communities in Area 3 will not be treated due to the interception of applied water by the canal.

  Area 5 is bounded on the West by Route 3134 and a levee, and on the south and east by a levee and a canal. It is split into two areas by a pipeline canal (Figure 4). The application of effluent in the northern end of the area will result in its flow through about 760 acres of marsh (emergent wetland in Figure 3), which should be included in treatment area calculation. If properly distributed, most of the portion of Area 5 east of the pipeline canal will be treated. However, west of the pipeline canal, only a portion (perhaps 50 percent) will be wetted because of the presence of canals and a stream channel.

FIGURE 3
Potential Wastewater Application Sites
Figure developed from 1999 Digital OrthoQuad Aerial photography and Exhibit 1, Nelson and Company, 2003. Areas drawn and acreage calculated using ARCVIEW and ARCINFO software.

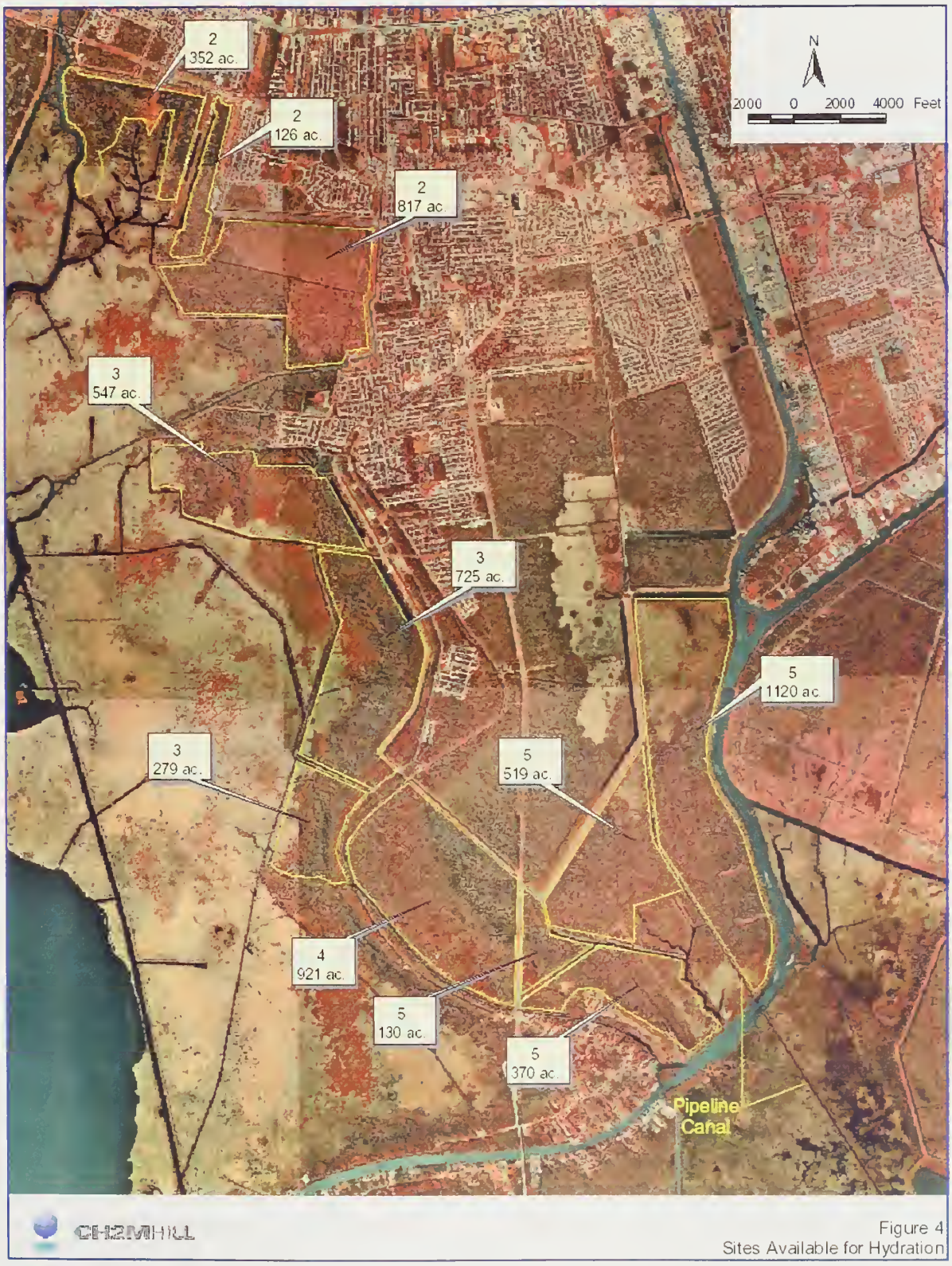

FIGURE 4
Best Wastewater Application Sites
Figure developed from 1999 Digital OrthoQuad Aerial photography and NWI Wetland Mapping information. Areas drawn and acreage calculated using ARCVIEW and ARCINFO.

Water Quality

A baseline report on water quality parameters from Maurepas Swamp (Day et al., 2003) and other available data on background water quality in a variety of southern wooded wetlands can be considered to develop general expectations of water quality in the Barataria Preserve sites where the effluent application is proposed.

Day et al. (2003) reported mean and range of water quality parameters for the major bayous and water bodies. These data and the data from several other reports on water quality in southern swamps (Mitsch and Gosselink, 1993; Dortsch, 1996; Ewel and Odum, 1994; Kadlec and Knight, 1996; CH2M HILL, 1985, 1995; and the North American Treatment Wetland Database [NADB], 1993) were used to develop some generalizations about the expected water quality of southern forested wetlands (Table 2). From these data, it does not appear that the typical water quality in Maurepas Swamp is greatly different from other sites reported. These data also suggest that the values in Table 2 could be considered as a general guide to treatment targets for effluent application in the Barataria Preserve.

Application of Effluent to the Park

The application of treated effluent to the Jean Lafitte National Park may improve basic ecological conditions there, particularly in the hardwood swamps. However, a number of issues should be considered as part of a feasibility evaluation. These issues are interdependent and in concert may result in greater impacts than when considered individually. This analysis is conservative to account for these synergistic effects that cannot be well quantified in a conceptual analysis:

- Stream channels, canals, and levees will greatly influence where the water goes and how long it remains in the swamp, and thus, the water quality treatment that can be expected.
- The vegetation communities have hydroperiod requirements that cannot be violated without, in the long-term, changing the nature of the plant community.
- The acreage that is nominally available and that area actually associated with hydrologic and water quality improvements may be quite different.
- Finally, the manner of application–how and where the water is introduced–also may greatly influence the overall benefit that the application provides.

Effects of Channels

Little water quality improvement should be expected once the water enters a channel. There are major canals cutting across and through the park and into the swamps on the eastern side of the Park. These channels will intercept the flow of water when that flow reaches them and rapidly transmit it to the water bodies at the end of the channel–namely Lake Salvador. Once a flow enters a channel, the primary benefit may be the displacement of potentially saltier water with fresher water. Thus, a hydrologic augmentation should include a hydraulic model to estimate the effects of different locations and application rates on water residence time and areas of influence. A number of application points may provide for greater treatment area and water quality improvement than a single point of application.

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TABLE 2
Summary of Background Water Quality Parameters for Southeastern Swamps and Recommended Pretreatment Levels Prior to Treatment in Forested Wetlands

Parameter	Number of Systems	Southeastern Swamps Background Water Quality Mean (Range)	Recommended Inflow Values for Swamp Treatment Wetlands	Maurepas Swamp Mean (Range)
Chemical Oxygen Demand	6	3.0 (1.0 – 7.0) as BOD_5	<20	NA
Total Organic Nitrogen	4	1.0 (NA)	NA	NA
Nitrate + Nitrite Nitrogen (NO x)	5	0.0 (0.01 – 1.19)	NA (nitrification desirable)	0.007 (ND-0.143)
Ammonia Nitrogen (NH4)	7	0.02 (0.01 – 1.71)	< 5	0.008 (ND – 0.048)
Total Nitrogen (TN)	7	1.0 (0.6-9.7)	< 20	0.577 (0.193-1.285)
Total Suspended Solids (TSS)	4	6.1 (0.1 – 14.0)	< 20	16 (4 – 101)
Total Phosphorus (TP)	8	0.14 (0.08 - .66)	< 1	0.055 (0.022 - .424)
pH	7	4-8 (site specific)	NA	NA
Dissolved Oxygen	8	0.3 – 5.2 (site specific)	NA	NA

Notes:
NA = information not available
ND = non-detectable
All values reported as mg/L, except for pH.
Source: Kadlec and Knight, 1996

Effects on Vegetation Communities

The target vegetation communities are hardwood swamps on the eastern side of the Park. These vegetation communities (a large portion of which are seen in Figure 3) are of two general types, broadleaf deciduous and cypress dominated communities, that probably will have similar hydroperiod requirements and nutrient uptake characteristics for optimal productivity. They are both at risk from the combination of land subsidence and saltwater encroachment, although the subsidence may be a much more significant factor than increasing average total dissolved solids concentrations. These communities are seasonally or frequently inundated. To sustain productivity and health, water levels need to fluctuate sufficiently to provide regular (annual or every other year) periods of exposed substrate that allow for recruitment and survival of seedlings and maximum continued growth of samplings and adult trees (Middleton, 1999). Adult cypress are the most tolerant of wetland tree species for standing water, and even they will eventually succumb to long-term inundation in deep (greater than about 4 feet) water (Middleton, 1999; and Conner and Buford, 2001). Cypress–Hardwood associations such as those currently dominating the Park

have developed under conditions of large differences between wet and dry seasons that favor a mixture of species. Increasingly wet conditions could lead to a reduction of biomass associated with other hardwoods, and permanent inundation could lead to a thinner (lower biomass community) with relatively low productivity, dominated by only the most tolerant adults of cypress or cypress and tupelo (Conner and Buford, 2001). Mixed deciduous species are less tolerant of constant flooding than are cypress, and all need periods of exposed sediments for recruitment. On the other hand, high rates of drainage may favor a replacement of cypress tupelo forest with less tolerant species such as hickory water-oak associations (Conner and Buford, 2001).

In a scenario where the constant application of water and permanent standing water are predicted, seedling or sapling planting may be necessary to maintain the stand density for cypress and tupelo. It may not be possible to maintain other less tolerant competitors, even with a planting program.

Permanent emergent marsh is present in the area dominated by the hardwood swamps. The northernmost part of Area 5 and the eastern edge of the estuarine and scrub-shrub wetlands are emergent dominated (Figure 3). These systems may remain in the face of constant inundation, or may convert to floating marshes or floating aquatic plants under the right conditions. Large discharge sources that release flows with sufficient energy can create an area within which rooted plants cannot maintain themselves. This situation creates an opportunity for floating plants, such as water hyacinth or water lettuce, to become extremely successful, particularly if the nutrient concentration of the water is elevated. A lower energy discharge that raises and maintains water levels over the typical conditions under which the emergent marsh developed can lead to the uprooting of mats and the development of floating marshes, which may remain permanently, or may convert to open water.

Low-energy discharges at rates that do not increase the average high water levels have a greater likelihood of maintaining emergent marsh.

Decisions concerning canal plugging and the design of the effluent distribution system will provide the information necessary to determine the potential treatment wetland area. Assuming an optimal effluent distribution system and plugging only minor canals (Table 3), there will be a total of about 5,906 acres available for hydration. Most of this is forested wetland (swamp), but the site also includes 490 acres of marsh in Area 5 and smaller areas of emergent marshes in Area 3.

Application Benefits to Wildlife and Human Communities

It is now recognized that both wildlife and humans may benefit when treated effluent is properly applied to natural wetlands, particularly those in need of additional water. These benefits are beginning to be recognized as important, not marginal, to the health and maintenance of these natural systems.

TABLE 3
Treatment Acres Available Assuming Distributed Effluent Application and without Plugging or Crossing Large Canals

Area No.	Acres	Wooded Acres Available Without Plugging Large Canals
1	3,614	0*
2	3,823	1295
3	9,807	1,551
4	982	921
5	2,837	2139
Totals	**21,063**	**5,906**

Notes:
*No wooded acres are present in this area.
See Figures 2, 3, and 4 for areas associated with each area number and vegetation communities. Wooded acre values were calculated using ARCVIEW and ARCINFO software on 1999 Digital OrthoQuad Aerial Photography.

The wetlands of the Barataria Preserve need additional water. Levees created to protect human development and canals created to move materials and people through the wetlands have resulted in the reduction of the amount, quality, and timing of natural surface waters that the wetlands receive. This process has had a strong effect on the vegetation community. In swamps and marshes, vegetation changes have included loss of characteristic cypress swamps and their invasion by less water-tolerant species, and invasion by uplands species at the edges. Marshes have become more saline, resulting in a process of succession from freshwater to more salt-tolerant species.

The changes in water levels have a similar effect on the wildlife, although it is often less noticeable to the casual observer. Habitat and breeding areas for freshwater fish species that are an important source of recreational fishing are reduced where standing water is replaced by dry land, and are replaced by more salt-tolerant species with less interest to humans where the water becomes more saline. Bird species respond in the same way. Loss of habitat and prey items reduce their numbers, and freshwater species may be replaced by more saline-tolerant species in areas of salt-water intrusion. Migratory birds also are affected as the habitat becomes less suitable or disappears. Many migratory birds rest in freshwater marshes when they move north or south, and loss of suitable resting sites is a significant issue in migratory bird survival (Pranty and Basili, 1998).

The benefits to wildlife and humans from augmentation with properly treated wastewater are numerous. The Mississippi Flyway is one of the four main routes for annual bird migrations from North America to South America (http://migratorybirds.fws.gov/). Many of these are shorebirds and waterfowl. Habitat loss through development is a primary

problem for successful transcontinental migrations. Birds rest in flyway refuges for up to a few weeks, and often return to the same stopover sites year after year (Smith and Houghton, 1984; Lanctot and Laredo, 1994, cited in Pranty and Basili, 1998). Restoration of more typical hydrologic conditions in the Barataria Preserve areas where water is applied will support greater migratory and resident bird populations, as the water provides appropriate space and food for these species. In addition, birds, amphibians, reptiles, mammals, and invertebrates will benefit from this augmentation. Studies of constructed and natural wetlands used for the treatment of wastewater (CH2M HILL and Payne Engineering, 1997; Knight et al., 2001) have shown that the higher diversity of aquatic plant life, the increase in habitat complexity in constructed wetlands, and the more continuous nature of wetland and aquatic habitats in natural wetlands that receive wastewater are beneficial to the full range of aquatic wildlife and bird species that rely on these habitats. Worral et al. (1997) recognized the abilities of treatment systems to protect and create downstream wetlands "of conservation importance as well as wildlife resources in their own right."

When treatment wetlands are open to the public, they are used for a variety of activities, from bird watching to active play (running, biking, jogging, etc.) and as educational opportunities for the local community (Knight, 1997). Some treatment wetlands are open to hunting or fishing as well (Knight et al., 2001). Knight et al. (2001) provides human-use-day (HUD) data from the North American Wetland Treatment System Database (Knight et al., 1993) that demonstrate the high level of interest that some of these sites can generate.

The Bayou Segnette State Park, on the northwestern border of the Preserve, and Barataria Preserve itself are already popular recreational sites. Bayou aux Carpes (area #5 in Figure 3) is a "productive wetland system that is of significant value to many species of fish and Wildlife" (U.S. Department of the Interior, 1998). The maintenance and improvement of the hydrology in the proposed areas probably will result in additional human interest in visiting these areas. A plan to develop a recreational trail corridor along the Westwego to Harvey Canal Hurricane Protection Levee has been developed (U.S. Department of the Interior, 1998b) and will attract additional visitors, particularly if the hydrologic restoration is achieved.

Concerns with Wastewater Applications to Wetlands

Treated wastewater applications to wetlands may also generate concerns about mosquitoes and other biting insects and the transmission of disease or germs present in the water being applied. Insect pests and disease transmission are not problems in properly designed and managed treatment wetlands.

Mosquitoes and other biting insects are common in wetlands of all types. Mosquitoes in particular reach their maximum population potential in polluted conditions. They can tolerate low dissolved oxygen levels associated with highly polluted waters because they breath atmospheric oxygen at the surface of the water. In natural treatment systems, reported problems are rare (Kadlec and Knight, 1996). Mosquito problems probably are a result of excessive organic matter loading that reduces oxygen levels to the point where natural mosquito predators are limited. Wilson et al. (1987) found that organic matter loading greater than 80 kg/ha/d limited mosquito fish access to areas of a water hyacinth pond. Management of inflow quality to ensure that oxygen levels will be maintained is the key to mosquito management in this situation. An evaluation of expected organic loading

and its impact on oxygen levels should be performed as part of a detailed design to ensure that this problem does not occur. We could find no reports of problems with mosquitoes in Louisiana sites receiving treated wastewater. In addition, the maintenance of natural water levels for the swamps provides conditions that are less suitable for mosquito population explosions by maintaining the predator populations that keep mosquitoes under control. For instance, wetlands that receive only stormwater runoff are likely to go dry, resulting in the complete loss of mosquito fish, an important mosquito predator (Kadlec and Knight, 1996). As long as perennially flooded areas exist as refugia for mosquito predators, this should not be a problem.

The transmission of disease is unlikely for several reasons. First, direct water contact is not typically encouraged in treatment wetlands. Second, a relatively high level of treatment will be applied to these discharges, and that treatment is typically sufficient to eliminate many of the diseases associated with raw wastewater. Monitoring sufficient to ensure that the influent water is of sufficiently high quality and that the wetland is functioning as expected is a necessary component of any wetland treatment system. Finally, treatment wetlands effectively remove many pathogens common in wastewater (Kadlec and Knight, 1996). The conditions in wetlands are hostile to most pathogens, and elimination of these organisms is rapid and complete. Coliform bacteria, used as a general indicator of pathogen presence, and viruses have been found to be more than 90 percent removed in almost all treatment wetlands in short (1 to 3 days) periods. Kadlec and Knight summarized their evaluation of pathogen treatment in wetlands with the following statement: "Available information indicates that wetlands are at least as effective as other treatment technologies in reducing viral pathogen populations" (Page 544, 1996).

Hydrologic Application Rates and Expected Water Quality Treatment

Expected hydrologic and nutrient loads associated with the effluent discharge must be evaluated to make preliminary estimates of potential effects of effluent discharges on the Park lands.

Hydrologically, 40 million gallons per day (mgd) applied to 5,906 acres is about 0.6 centimeters per day (cm/d) or 0.2 inch per day. Current recommendations for hydrologic loading to swamps in Florida are 0.73 cm/d for unaltered woody wetlands and 2.18 cm/d for affected swamps. At two sites in Louisiana–Breaux Bridge and the City of Thibodaux–secondary effluent is discharged to wetlands at the rates of 0.03 cm/d and 0.6 cm/d, respectively. There have been no reports of hydrologically induced damage at those sites, and studies of primary production in similarly treated swamps have shown increases in both woody plant growth and rapid accretion of soils (Day et al., 1999).

Estimates of current treatment levels from the four secondary-level wastewater treatment plants (WWTPs) associated with the project show a relatively consistent range of performance (Table 4). A comparison of the results from all four WWTPs with respect to typical secondary treatment levels suggest that the plants are in general operating in the expected ranges, with effluent concentrations of 10 to 20 milligrams per liter (mg/L) total nitrogen (TN) and 2 to 5 mg/L total phosphorus (TP). The City of Amelia reported a low effluent TP concentration in its treatment well, but the total Kjeldahl nitrogen (TKN) data are in the same range as the other plants. The estimate of typical nutrient values for water quality treatment purposes focused on the performance of the Breaux Bridge, St. Bernard,

and Thibodaux WWTPs. Conservative estimates of 10 to 20 mg/L TN and 2 to 3 mg/L TP were used as inflow concentrations to estimate the final outflow concentrations from forested wetland areas treated with wastewater. The available data, provided in Table 4, are incomplete with respect to the fractions of N from all of the plants, but they suggest that a significant fraction of the inflow nitrogen may be in nitrate. It is, however, WWTP dependent (compare Beaux Bridges to Thibodaux nitrogen species concentration data).

Sufficient data are available to compare the treatment expected by average constructed wetland standards and the reported performance of Thibodaux and Breaux Bridge Wetlands using a constructed wetland design model provide by Kadlec and Knight, 1996 (Equation 19-9) that predicts the area necessary to reach a target concentration. This is a general mass balance wetland design model used here to illustrate the potential differences in areas required to reach the same target concentrations in a constructed wetland and in a natural wetland receiving treated effluent.

The Kadlec and Knight model was used to compare the area predicted to achieve the reported results for the Breaux Bridge and Thibodaux wetlands (Table 4). Also, the model estimated the area necessary to reach background levels for the Maurepas Swamp (Table 2), as well as the reported performance for the natural Louisiana wetlands. The model area predictions for reported phosphorus and nitrogen outflow concentrations were within the available areas for those wetlands (Table 5). However, to reach background levels, additional area would be necessary at Thibodaux. The primary difference between Thibodaux and Breaux Bridge is the much higher loading (4 mgd for 571 acres) that occurs at Thibodaux. However, it is also important to note that the actual area involved in treatment at Breaux Bridge probably is a fraction of the total area. Blahnik and Day (2000) found that about 60 percent of the surface water flow was concentrated in only 10 to 12 percent of the area at Breaux Bridge.

TABLE 4
Estimate of Expected Average Effluent TN and TP Concentrations Applied to Wetlands

WWTP	Wetland Area (Acres)	Inflow (mgd)	N Species Reported	N Inflow (mg/L)	N Outflow (mg/L)	P Species Reported	P Inflow (mg/L)	P Outflow (mg/L)
Amelia	NA	NA	TKN	2.98	1.00	TP	0.73	0.06
Breaux Bridge	3,645	~1	NO3	0.8	0.06	TP	2.90	0.30
St. Bernard	NA	NA	TKN	13.6	1.40	TP	3.29	0.23
Thibodaux	571	4	TKN	2.9	0.90	TP	2.46	0.85
Thibodaux	571	4	NO_3	8.7	<0.1	PO_4	1.9	0.6
High estimate, average TN			**20 mg/L**		**High estimate, average TP**		**3 mg/L**	
Low estimate average TN			**10 mg/L**		**Low estimate average TP**		**2 mg/L**	

Notes:
WWTP = wastewater treatment plant
NA = data not available
mg/L = milligrams per liter
WWTP discharge concentration data from Nelson (2003).

TABLE 5
Acres Estimated by Kadlec and Knight Model to Achieve Reported P and N Outflow Concentrations (Table 4) and Estimated Background Values (Table 2)

Site	Acres Predicted for outflow P reported (Table 4)	Acres Predicted to Reach Background P (Table 2)	Acres Predicted for outflow N reported (Table 4)	Acres Predicted to Reach Background N (Table 2)
Breaux Bridge	70	226	515	1,098
Thibodaux	126	885	2,175	4,343

The current understanding of nitrogen and phosphorus removal in southern forested wetlands has been analyzed by Lockaby and Walbridge (1998). They cited removal efficiencies of between 22 and 89 percent for nitrogen and between 20 and 80 percent for TP. Long-term storage generally is associated with soil storage of refractory organic materials containing P (Richardson, 1999). On the basis of an analysis of data in the NADB, he concluded that to permanently store P and prevent downstream movement of elevated P concentrations, P loading within a wetland must be below 1 gram per square meter per year ($g/m^2/yr$). Wetlands can continue to assimilate additional P as loading increases, but with higher outflow P concentrations. He also concluded that a conservative estimate of long-term P storage for wetland ecosystems not specifically designed to treat wastewater was between 0.4 and 1.4 $g/m^2/yr$.

Kadlec and Knight (1996: page 659, Table 22-1) developed conservative rules for WWTP discharge to natural wetlands. They suggested that effluent with a 5-day biochemical oxygen demand (BOD_5) of 20 to 30 mg/L, total suspended solids (TSS) of 30 to 50 mg/L. Additionally, they recommend a nitrified nitrogen component with a maximum of 5 mg/L ammonium and TN less than 20 mg/L. A TP inflow concentration of less than 1.0 mg/L reflects the long-term assimilation and storage rates seen in most natural wetlands. They also suggested that metals and other toxins present in the inflow be below chronic toxicity levels.

For the proposed discharge, a well-nitrified effluent containing 10 mg/L TN and 2 mg/L TP may well meet nitrogen, but not phosphorus, background standards. Using the Kadlec and Knight equation, nitrogen could be treated to background conditions (0.58 mg/L N) in about 4,250 acres. However, 4,280 acres were predicted to achieve a final concentration of 0.1 mg/L TP, and also, 8,608 acres are needed as a treatment area to reach a background concentration of 0.05 mg/L TP. A 1.0-mg/L TP inflow concentration treated to 0.05-mg/L TP would require a little less than 8,000 acres.

These predictions are based on the assumption that the treatment occurs in a carefully designed constructed wetland. Given the difference in area predicted and that necessary to achieve reported TP treatment levels in Louisiana, an increase in area or a decrease in inflow P concentrations may be necessary.

An important factor in the actual treatment that the water receives is the fraction of the total area that will be involved in removal of phosphorus. No wetland system is uniform in terms of the flow regimes within it, or the residence times in different areas. Treatment

effectiveness is a result of the summed result of a range of performances. Constructed wetlands designed for optimal performance may not see greater than 75 percent of the total surface area associated with active removal. The conservative design of natural wetland treatment systems also should incorporate at least twice the area estimated for pollutant removal to allow at least one-half the area to rest at any time (Kadlec and Knight, 1996). This approach will allow for the propagation of woody species, development of aerated soil conditions, etc., as occurs naturally during the annual and longer-term hydrologic cycles when water levels fall.

Potential Risks and Benefits of Effluent Application

The risks and benefits of applying treated wastewater to the Park are magnified by the fact that the site under discussion is a national park. Any potential damage or perception of damage caused by an application will be magnified in the public eye. This consideration should lead to a conservative application design, in particular to ensure that no trees are inundated to the point of reduced production or death, and that propagation and growth of young trees is not inhibited by continual flooding. Other effects, such as production of algal scums not typically present, odors, discolored water, or water leaving the Park treatment area that violate standards, also will result in great damage to the important benefits that such an application at this site can have.

This area of Louisiana is subsiding and sea levels are rising. Increased biological production has led to an increased accumulation of wetland soil in Louisiana, as well as in other locations receiving water with increased nutrient levels. In this area, the benefit of increased accumulation cannot be overstated, because it results in a partial balance of the subsidence.

The addition of freshwater will result in less opportunity for intrusion of more saline water, and if properly managed, provide a partial replacement of the annual flooding cycle once provided by the Mississippi River. Although this application will not provide sediments, it will provide some accretion benefits, as indicated above.

Summary Recommendations

The proposed application is a novel approach to the preservation and management of a sensitive and important site. Subsequent analyses may greatly extend or alter the recommendations provided herein or add additional recommendations. The application of treated wastewater may be the best means of meeting the goals of preserving the ecosystem within the preserve and simultaneously solving issues associated with the human population in the area.

A WWTP effluent application to the natural wetlands in the Jean Lafitte National Park/ Barataria Preserve may be beneficial (Day et al., 1999; and Nelson, 2003), but a careful and detailed consideration of the site, the effluent, and the background water quality and expected treatment levels should be fully explored before a decision is finalized.

Recommendations concerning the WWTP discharge to the Barataria Preserve, based on this initial analysis, include the following:

1. Only a highly nitrified effluent with a TN concentration not greater than 10 mg/L should be applied to the wetland swamps. The available area may effectively treat a 40-mgd flow of this TN concentration and composition.

2. TP concentrations in the effluent should be reduced significantly, compared to the currently projected 2 to 3 mg/L TP. A careful analysis should be conducted to identify how much phosphorus can be assimilated on a long-term basis given the nature and size of the receiving wetland.

3. Background concentrations will need to be established and discussions with the regulatory community will be necessary to identify those levels and to identify target treatment levels for both TN and TP.

4. The distribution system for the wastewater will need to be as extensive as possible to ensure the greatest effective treatment area. The hydraulic loading should be designed to ensure that the area can be "rested," thus allowing the soil to be exposed and seedling recruitment and young tree growth to continue.

5. Consideration should be given to reducing the proposed application flow rate of 40 mgd. A lower application rate of a more highly polished effluent might provide the same level of benefits to the Park and reduce the risks to the Park environment.

References

Blahnik, Theodore and John Day, Jr. 2000. "The Effects of Varied Hydraulic and Nutrient Loading Rates on Water Quality and Hydrologic Distributions in a Natural Forested Treatment Wetland." *Wetlands*, 20(1):48-61.

Cowardin, L. M, V. Carter, F. C. Golet, and E. T. LaRoe. 1979. *Classification of Wetlands and Deepwater Habitats of the United States.* U.S. Fish & Wildlife Service Publication FWS/ OBS-79/31, Washington, D.C. 103 p.

CH2M HILL. 1985. Deer Park Wetlands Engineering and Environmental Report. Prepared for Pasco County Utilities, 4025 Moon Lake Road, New Port Richey, Florida 33522.

CH2M HILL. February 1988. *Okahumpka Swamp Baseline Monitoring Study Interim Report, July – December 1987.* Prepared for the City of Leesburg, Florida.

CH2M HILL. 1988. *Okahumpka Swamp Baseline Monitoring Study. Final Report, July 1987 – December 1988.*

CH2M HILL. 1990. *Grand Strand Water and Sewer Authority Central Wastewater Treatment Plant Wetland Discharge: Central Slough Pilot Study. Fourth Annual Report, July 1989-1990.*

CH2M HILL. January 1995. *Great Swamp Effluent Management System Baseline Monitoring Report. Summary Report December 1993 – November 1994.* Prepared for the Beaufort-Jasper Water and Sewer Authority P.O. Box 2149 Highway 170, Beaufort, SC. 29902.

CH2M HILL and Payne Engineering. 1997. *Constructed Wetlands for Livestock Wastewater Management. Literature Review, Database, and Research Synthesis.* Report Prepared for the Gulf of Mexico Program, Nutrient Enrichment Committee, Stennis Space Center, MS.

Conner, William H. and Marilyn A. Buford. 1998. "Southern Deepwater Swamps." Chapter 11, pages 261-290 in: *Southern Forested Wetlands*, Ecology and Management. CRC Press LLC of Lewis Publishers,. Boca Raton, FL. 616 pp.

Day, John W., Robert R. Lane, G. Paul Kemp, Hassan S. Mashriqui, and Jason N. Day. 2003. *Mississippi River Diversion into the Maruepas Swamp. Water Quality Analysis – Draft Final Report.* www.savelawetlands.org/site/Projects/ PO29/attachment_f_nutrients.pdf.

Day J. W., Jr., J. M. Rybczyk, L. Cardoch, W. H. Conner, P. Delgado-Sanchez, R. I. Pratt, and A. Westphal. 1999. "A Review of Recent Studies of the Ecological and Economic Aspects of the Application of Secondarily Treated Municipal Effluent to Wetlands" in: Rozas L. P., J. A. Nyman, C. E. Proffitt, N. N. Rabalais, D. J. Reed, and R. E. Turner (editors). *Southern Louisiana from the Symposium Recent Research in Coastal Louisiana: Natural System Function and Response to Human Influence.* Published by Louisiana Sea Grant College Program.

Dortch, M. S. 1996. "Removal of Solids, Nitrogen, and Phosphorus in the Cache River Wetland." *Wetlands.* 16(3): 358-365.

Ewell, Katherine Carter and Howard T. Odum (Editors). 1984. *Cypress Swamps.* University of Florida Press. Gainesville FL 32603. 472 pp.

Huslander, Bill. April 4, 2003. Personal communication. Jean Lafitte National Park Resource Manager.

Kadlec, R. H. and R. L. Knight. 1996. *Treatment Wetlands*. CRC Press, Inc. U.S.A.

Kadlec, R. H. and R. L. Knight. 1996. *Treatment Wetlands*. Lewis Publishers, Boca Raton, FL. 893 pp.

Knight, R. L. 1997. "Wildlife Habitat and Public Use Benefits of Treatment Wetlands." *Water Science & Technology*. 35(5):35-43.

Knight, R. L., R. W. Ruble, R. H. Kadlec, and S. C. Reed. 1993. *North American Wetlands for Water Quality Treatment Phase II Report*. Prepared for EPA, September 1993.

Knight, R. L., R. A. Clarke, Jr. and R. K. Bastian. 2001. "Surface Flow (SF) Treatment Wetlands as a Habitat for Wildlife and Humans." *Water Science & Technology* 44(11): 27-37.

Lanctot, R. B. and C. D. Laredo. 1994. Buff-Breasted Sandpiper (*Tryngites subruficollis*) in: a. Poole and F. Gill (Eds.) The Birds of North America, Number 91. Academy of Natural Sciences, Philadelphia, PA, and American Ornithologists' Union, Washington, D.C. 20 pp.

Lockaby, Graeme B. and Mark R. Walbridge. 1998. "Biogeochemistry." Chapter 7, pages 149-172 in: Reddy, K. R., G. A. O'Conner, and C. L. Schelske (Eds.): *Phosphorus Biogeochemistry in Subtropical Ecosystems*. Lewis Publishers, Boca Raton, FL. 707 pp.

Middleton, Beth. 1999. *Wetland Restoration, Flood Pulsing, and Disturbance Dynamics*. John Wiley & Sons, Inc. 388 pp.

Mitsch, William J. and James G. Gosselink. 1993. *Wetlands, Second Edition*. Van Nostrand Reinhold, New York. 722 pp.

North American Treatment Wetland Database (NADB). 1993. Electronic database created by R. Knight, R. Ruble, R. Kadlec, and S. Reed for the U.S. Environmental Protection Agency. Copies available from Don Brown, EPA, (513) 569-7630.

Nelson, Waldemar S. and Company, Inc. 2003. *Wetlands Restoration Jefferson Parish West Bank. Phase I Report*. Prepared for New Orleans District U.S. Army Corps of Engineers. Job No. 20020109.

Pranty, Bill, and Gianfranco D. Basili. 1998. *Bird Use of Agricultural Fields at Lake Apopka, Florida with recommendations for the Management of Migratory Shorebirds and other Species*. Publication of the Florida Audubon Society. 1331 Palmetto Avenue, Winter Park, Florida 32789. September 22, 1998. 30 pp.

Richardson, C. J. 1999. "The Role of Wetlands in Storage, Release, and Cycling of Phosphorus on the Landscape: a 25-year Retrospective." Chapter 2, pages 47-68 in: Reddy, K. R., G. A. O'Conner and C. L. Schelske (Eds.). *Phosphorus Biogeochemistry in Subtropical Ecosystems*. Lewis Publishers, Boca Raton, FL. 707 pp.

Smith, P. W. and N. T. Houghton. 1984. "Fidelity of Semipalmated Plovers to a Migration Stopover." *Journal of Field Ornithology*. 55:247-249.

Spicer, Bradley E,. S. Dayton Mathews, Ray E. Dance, Kent R. Milton, and William E. Boyd. 1985. *Soil Survey of Jefferson Parish, Louisiana*. U.S. Department of Agriculture Soil Conservation Service, in Cooperation with the Louisiana Agricultural Experiment Station.

U.S. Department of the Interior. 1996. *Boundary Study/Environmental Assessment*. Barataria Preserve Unit Jean Lafitte National Historical Park and Preserve. U.S. Department of the Interior, National Park Service, Denver Service Center. October 1996.

U.S. Department of the Interior. 1998. *Recreational Trail Corridor Concept and Design Recommendations*. Westwego to Harvey Canal Hurricane Protection Levee Louisiana. Prepared for the U.S. Army Corps of Engineers, New Orleans District, by the U.S. Department of the Interior, National Park Service, Denver Service Center. November 1998.

White, D. A., S. Darwi, and L. Thien. 1983. "Plants and Plant Communities of the Core Area Jean Lafitte National Historical Park." *Tulane Studies Zoology & Botany*. 24:101-129.

Wilson, B. A., K. R. Townsend, and T. H. Anderson. 1987. "Mosquito and Mosquitofish Responses to Loading of Water Hyacinth Wastewater Treatment Ponds." Pp. 807-808 in: K. R. Reddy and W. H. Smith (Eds.). *Aquatic Plants for Water Treatment and Resource Recovery*. Magnolia Publishing, Orlando, FL.

Worral, P., K. J. Peberdy, and M. C. Millett. 1997. "Constructed Wetlands and Nature Conservation." *Water Science & Technology*. 35(5):205-213.